TP 5116E

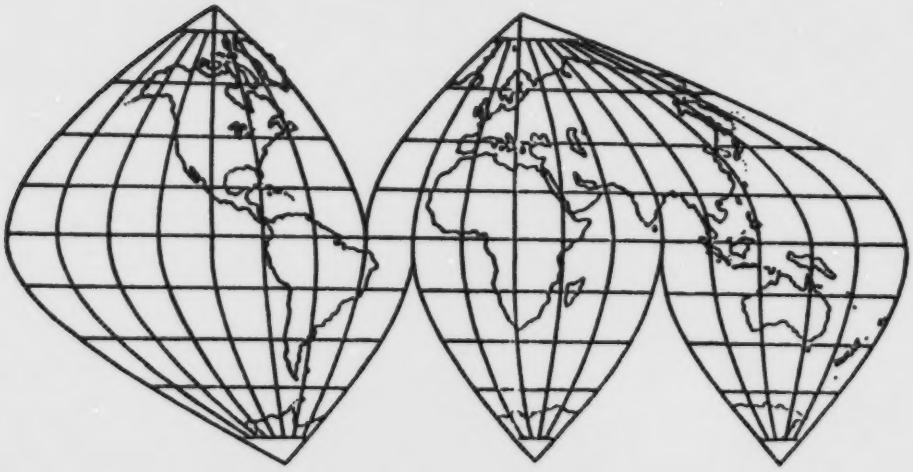
STUDY OF AEROBAC AB-7 VEHICULE FOR AIRPORT RESCUE IN DIFFICULT TERRAIN

AIRPORTS STUDIED:
VANCOUVER INTERNATIONAL
BAIE-COMEAU

PREPARED FOR THE
TRANSPORTATION DEVELOPMENT CENTRE
OF TRANSPORT CANADA

by

P.F. Alepin, B. Gauthier, Dr. R.N. Yong



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in collaboration with

Vitri
Dr. R.N. Yong
McGill University Geotechnical Research Centre
M. Letendre et Associés
SNC

Un sommaire en français de ce rapport est inclus avant la table des matières

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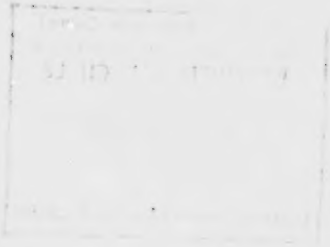
December 1983

The content of this report reflects the views of the contractor and not necessarily the official views or policies of the Transportation Development Centre of Transport Canada.



PROJECT TEAM

The project team was composed of:

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Dr. R.N. Yong	Geotechnical and Vehicle Performance Expert,	
Dr. P. Boonsinsuk	Senior Geotechnical Engineer,	McGill University
Mr. N. Skiadas	Geotechnical Engineer,	McGill University
Mr. M. Letendre	Vehicle Design Expert,	Letendre & Ass.
Mr. D. Gawish	Aerobac Design Consultant,	SNC

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17. Abstract

This report describes a study to analyse the effectiveness of the Aerobac AB-7, a 7-tonne payload tracked air-cushion vehicle under development, used as a crash fire-fighting and rescue vehicle at airports with difficult terrains and to determine the costs and schedule for the construction of a prototype and 10 units. Vancouver International and Baie-Comeau airports were selected as sites for tests comparing the performance of the Aerobac AB-7 and that of an existing airport CFR wheeled vehicle, the Foremost Delta Three B-4S.

A complete terrain analysis was performed at both airports, including an investigation of the soil conditions. The response times from a specified location to possible crash sites were evaluated for the proposed and referenced vehicles using the NATO Reference Mobility Model (NRMM).

Test results show that the Aerobac remains mobile and can achieve a reasonable response time in deep snow (Baie-Comeau) and in mudflat (Vancouver) where the Foremost is immobilized. The Aerobac speed remains superior to the Foremost in marginal terrains (muskeg). The air-cushion lift is responsible for the superior performance of the Aerobac as it broadens the types of terrain over which it can perform compared to conventional vehicles.

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	Jacques E. Laframboise

17. Résumé

Ce rapport décrit une étude analytique d'évaluation des performances de l'Aérobac AB-7 utilisé comme véhicule d'urgence aéroportuaire dans des terrains difficiles. L'Aérobac est un véhicule hors-route et amphibie intégrant une traction à chenilles et une sustentation à coussin d'air. Les coûts de fabrication et un échéancier de l'approvisionnement pour la construction d'un prototype et de 10 véhicules de production sont aussi présentés.

L'aéroport international de Vancouver et celui de Baie-Comeau ont été choisis pour évaluer les performances de l'Aérobac AB-7 en terrains difficiles (plage boueuse, muskeg, neige). Il est comparé à un véhicule d'urgence aéroportuaire tout-terrain, le Foremost Delta Three B-4S.

Une analyse complète des terrains a été entreprise aux deux aéroports, comprenant une étude des conditions de sol. Les temps de réponse d'un endroit spécifié à des sites possibles d'écrasement ont été évalués en utilisant le modèle de référence de mobilité NATO (NRMM) pour les deux véhicules.

L'étude des temps de déplacement démontre que l'Aérobac garde sa mobilité et peut obtenir un temps de réponse raisonnable dans la neige profonde (Baie-Comeau) et dans la boue liquide (Vancouver) où le Foremost est embourbé. La vitesse de l'Aérobac demeure supérieure au Foremost sur les terrains marginaux (muskeg). Cette performance supérieure de l'Aérobac provient de la sustentation à coussin d'air permettant de négocier un éventail élargi de terrains comparativement aux véhicules conventionnels.

18. Mots-clés	19. Diffusion
Aérobac, véhicule tout-terrain, coussin d'air, amphibie, aéroport, écrasement, protection incendie.	Le CDT dispose d'un nombre limité d'exemplaire.

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Special thanks to the following persons for providing detailed explanations of rescue problems encountered and clarification of needs:

Mr. Lorne D. Howell	Vancouver International Airport, General Manager
Mr. Eric Davison	Vancouver International Airport, Operations Manager
Mr. Gil Fanslau	Vancouver International Airport, Fire Chief
Mr. John McGrath	Vancouver Coast Guard Hovercraft Base Manager
Mr. Marc Beaumont	Baie-Comeau Airport, Manager
Mr. Daniel Desrosiers	Baie-Comeau Airport, Fire Chief
Mr. Jacques Cardinal	Mirabel Airport, Fire Chief

SOMMAIRE

Il est démontré dans cette étude que l'Aérobac AB-7 est capable d'être utilisé comme un véhicule d'urgence et de protection incendie en cas d'écrasement d'avions dans les aéroports. Il est supérieur aux véhicules tout-terrain utilisés présentement lorsque des sols de faible portance ou de la neige profonde doivent être traversés.

L'Aérobac AB-7 est un véhicule hybride, tout-terrain et amphibie. Il intègre une traction à chenilles avec une sustentation à coussin d'air. Il est élaboré selon un concept du Centre de développement des transports. L'aéroport international de Vancouver et celui de Baie-Comeau ont été choisis pour évaluer les performances de l'Aérobac AB-7 sur des terrains difficiles (plage boueuse, muskeg, neige).

L'étude analytique d'évaluation des performances de l'Aérobac AB-7 révèle la supériorité de ce véhicule comparativement à un autre véhicule tout-terrain: le Foremost Delta Three B-4S. En effet, l'étude des temps d'intervention démontre que l'Aérobac garde sa mobilité et peut obtenir un temps de réponse raisonnable dans la neige profonde à l'aéroport de Baie-Comeau et dans la boue liquide à l'aéroport international de Vancouver où le Foremost s'embourberait. Sur les terrains difficiles tels que le muskeg, sa vitesse est supérieure à celle du Foremost. Cette maniabilité de l'Aérobac provient de la sustentation à coussin d'air permettant de négocier un éventail élargi de terrains comparativement aux véhicules classiques.

Une analyse complète des terrains a été entreprise aux deux aéroports, suivie d'une étude des conditions de sol. Les temps d'intervention pour atteindre des sites possibles d'écrasement ont été évalués en utilisant le modèle de référence de mobilité NATO (NRMM) pour les deux véhicules.

Le coût de l'ingénierie et de la production du prototype de l'Aérobac AB-7 est estimé à 768.000$, plus 92.000$ pour l'équipement incendie. Le prix d'un véhicule équipé est estimé à 550.000$ (1983) pour un rythme de fabrication de dix véhicules annuellement. Le prototype serait disponible pour des essais douze mois après le début des travaux d'ingénierie.

L'Aérobac est recommandé sur des terrains où la neige abonde, sur des plages boueuses ou des endroits marécageux, tels que muskeg. L'étude démontre que l'Aérobac serait le seul véhicule terrestre demeurant mobile dans toutes ces conditions, tout en conservant un temps d'intervention raisonnable. Avec de tels résultats positifs il est recommandé que le programme de réalisation de l'Aérobac se poursuive et qu'une démonstration ait lieu afin de confirmer les études théoriques entreprises.

SUMMARY

It is demonstrated in this study that the Aerobac AB-7 is capable of performing as an airport crash-fire-fighting and rescue vehicle. It is superior to other all-terrain vehicles now used when low soil strength or deep snow have to be traversed.

The Aerobac AB-7 is an off-road and amphibious hybrid vehicle. It incorporates a conventional caterpillar traction with an air-cushion lift. Its design is based on a concept developed by the Transportation Development Centre. Vancouver International and Baie-Comeau airports were selected for evaluating the performance of the Aerobac AB-7 in difficult terrain, i.e. mudflat, muskeg, snow.

The analytical evaluation study of the performance of the Aerobac AB-7 reveals the superiority of this vehicle as compared to an existing all-terrain vehicle, the Foremost Delta Three B-4S. Indeed, tests results show that the Aerobac remains mobile and can obtain a reasonable response time in deep snow at Baie-Comeau airport and in mudflat at Vancouver International Airport where the Foremost is immobilized. The Aerobac speed remains superior to the Foremost in marginal terrains of muskeg type.

The superior efficiency of the Aerobac depends highly on the air-cushion system which is used to relieve the track bearing pressure. The use of air-cushion lift broadens the type of terrain that can be negotiated relatively to a conventional surface vehicle.

A complete terrain analysis was performed at both airports followed by an investigation of the soil conditions. The response times from a specified location to possible crash sites were evaluated for the proposed and reference vehicles using the NATO Reference Mobility Model (NRMM).

The engineering and manufacturing costs of the Aerobac AB-7 prototype has been estimated at 768.000$ plus 92.000$ for the crash-fire equipment The 1983 price of an equipped unit has been estimated at 550.000$ for a production rate of ten vehicles a year. A prototype would be available for tests and demonstration about twelve months after beginning of engineering work.

The Aerobac is recommended for conditions where snow abounds, in presence of large mudflat or muskeg areas of low soil strength. The Aerobac may then be the only surface vehicle capable of performing in these conditions while maintaining a reasonable reaction time.

With such positive results, it is recommended that the Aerobac realisation program proceed and that a demonstration of this new vehicle be performed to confirm the results of the theoretical studies.

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1. INTRODUCTION

1.1 The Mandate

The Transportation Development Centre (TDC), Transport Canada, contracted, on March 1983, to Intercan Logistical Services Limited a study of the evaluation of the Aerobac AB-7 vehicle used in an airport emergency and rescue function.

1.2 The Aerobac Concept

The Aerobac AB-7 is a hybrid off-road and amphibious vehicle designed with caterpillar traction and with an air-cushion system which has the effect of varying the weight supported by the tracks. The idea is for the driver to be able to modify ground contact pressure as required by terrain conditions.

The Aerobac concept extends the domain of operation of conventional off-road vehicles in that it should:

a) Permit relatively high speed movement over muskeg, muddy terrain or snow.
b) Permit crossing of small lakes and streams.
c) Operate off-cushion over the same types of terrain that are accessible to conventional off-road vehicles.

The Aerobac does not purport to replace existing off-road vehicles, helicopters or other form of transportation that operate satisfactorily under specific ground conditions suited to their use. The vehicle is more complex and larger than a conventional off-road vehicle of equivalent capacity and therefore, more costly. Its use is foreseen for areas where organic terrain or other low-bearing strength soils would unduly reduce the mobility of other off-road vehicles, or, when freezing and thawing periods reduce the strength of otherwise passable terrain.

1.3 Transport Canada Air Administration Interest

Airport Services and Security (KSE/A) of Transport Canada Air Administration have shown an interest in the studies conducted by TDC which led to the design of the Aerobac AB-7.

The vehicle concept, due to its low bearing pressure, appealed to KSE/A as a potential vehicle to satisfy their requirements. Conventional or "all terrain" wheeled vehicles are impaired in their operation in difficult ground conditions similar to those found at the Vancouver International and Baie-Comeau airports.

At the request of KSE/A, TDC, which is the R&D arm of Transport Canada, commissioned the undertaking of this study which is to be used in the decision making process pertaining to the fabrication of a prototype vehicle and its demonstration program at one or more airports.

1.4 Project Objective

Evaluate and analyse the effectiveness of the Aerobac AB-7 as an airport emergency service rescue vehicle for operation within the Critical Rescue and Fire-fighting Access Area (CRFAA) and within airport boundaries at airports where soil conditions make access with existing rescue vehicles slow or impossible. The CRFAA extends 150 m on both sides of the centreline and 1,000 m beyond either end of the runway.

1.5 Study Objectives

The following two objectives have been set:

1.5.1 Analyse the effectiveness of the Aerobac AB-7 at two specific airports: Vancouver International, British Columbia and Baie-Comeau, Québec. The vehicle-terrain response shall be based on the Aerobac AB-7 Technical Feasibility Report TP-3507F, dated March 1982, except for its power train capability which is upgraded as described in Section of this report. Evaluate and compare its performance to a reference wheeled vehicle.

1.5.2 Evaluate the procurement costs and schedule of an Aerobac AB-7 vehicle in an airport rescue function including those of a demonstration program.

1.6 Report Organization

The report is presented in the following sequence: Section 1, the Introduction, provides the mandate and the background of this study. Section 2 describes the study organization, Section 3 presents the operations and conditions of airport crash fire-fighting and rescue. Section 4 describes the terrain identification performed at two airports. Section 5 provides an analytical evaluation of running speed of the Aerobac. Sections 6, 7 and 8 discuss the engineering and procurement aspects of a CFR Aerobac vehicle. Section 9, the last section, presents the conclusions and recommendations.

2. STUDY ORGANIZATION

2.1 Project Administration

The study was under the administration of Mr. Jacques E. Laframboise, Senior Development Officer, TDC.

A Transport Canada consultative committee has contributed to the advancement of the study. Committee members were:

Messrs	N.E. Rudback,	TDC
	M. Audette,	TDC
	R.L. Burkill,	Air Administration
	R.M. Cyr,	Air Administration

2.2 Background

The ongoing Aerobac program is aimed at moving the development from the concept of this new advanced vehicle to its industrialization. A technical feasibility study was completed in 1982. (Ref. 1 and 2).

The present study fits naturally in the program. It tends to add momemtum towards a decision on the potential fabrication of the Aerobac and its implementation in real applications.

The airport rescue mission is seen as an additional application for the Aerobac. This study is thus aimed at increasing its potential use in meeting presently unsatisfied needs in the transportation sector.

2.3 Project Team

A team of experienced professionals was gathered taking into consideration the specialized expertise required in this particular study. Two members previously involved in the Aerobac program ensured its continuity.

The project team comprised the following members:

P.F. Alepin
- The project manager was project manager for the two initial studies on the Aerobac:

  i- Preliminary Development Study and
  ii- Technical Feasibility Study.

B. Gauthier
- The logistics expert has considerable operations and consulting experience in the field of specialized transportation systems and air-cushion transportation systems.

Dr. R.N. Yong
- The geotechnical and vehicle performance expert is a world specialist on vehicle terrain interaction for both military and civil applications; he has performed numerous studies of hybrid air-cushion vehicles.

Dr. P. Boonsinsuk and N. Skiadas
- Two geotechnical engineers from McGill University Geotechnical Research Centre were responsible to provide and analyse the basic terrain data which were obtained from field surveys and laboratory tests.

M. Letendre
- A specialized vehicle design consultant conducted a review of the Aerobac design under its new potential application and prepared the cost and schedule estimates of the fabrication of the vehicle and of its demonstration program.

D. Gawish
- The Aerobac design consultant was the project engineer responsible for the previous technical feasibility study.

2.4 Tasks

The study was divided as follows:

1- Information gathering
2- Terrain identification
3- Vehicle performance evaluation
4- Fire-fighting rescue equipment specification
5- Vehicle engineering review, procurement cost and schedule.

The project start-up was launched at a meeting of the study team with the consultative committee. The study mandate and work plan were discussed and reviewed.

Messrs. C. S. Heed and A. O. Dumas, regional managers for the Pacific and Québec airports, respectively, provided their support. The fire chiefs and operations managers of Vancouver International and Baie-Comeau airports provided information and assisted the project team all along the study. Information was also gathered from the Emergency Services personnel at Mirabel International Airport, which is a category No. 9, the highest category in Canada.

The project officer and two members of the study team went to France to discuss technology transfer for the proposed air-cushion ystem developed by SEDAM. SEDAM, a participant to the Aerobac technical feasibility study, ceased to exist as of April 30, 1983. The ownership of the SEDAM air-cushion system patents has been transferred to the French Government who had financed their development.

The transfer of technology was discussed with Le Centre National d'Exploitation des Océans who expressed its willingness to negotiate an agreement in the implementation of the Aerobac program. Skirt and fan manufacturers who contributed to the previous study were also visited.

A complete terrain identification was performed at both airports, with particular emphasis on the recongnition of obstructions to trafficability and unfavourable soil conditions. The soil investigated at each airport covered the Crash Rescue and Fire-Fighting Access Area. The Vancouver airport has two runways, Baie-Comeau has one.

The performance of the Aerobac AB-7 is evaluated and compared to a reference wheeled vehicle, the Foremost Delta Three B-4S. The terrain information referred to above is used as an input. Other inputs include vehicle specifications of the Aerobac and the Foremost. The mobility of the two vehicles is analysed using the NATO reference Mobility Model (NRMM).

The fire-fighting equipment for the Aerobac was studied. The capacity of the water reservoir is 4,500 ℓ. This equals existing equipment in service. Three Canadian fire-fighting vehicle manufacturing firms were contacted. Design requirements and equipment specifications applicable to the Aerobac AB-7 were defined.

A review of the Aerobac design concept is made taking into consideration the airport rescue operation application. In this regard, the speed specifications of the vehicle are upgraded. A summary is prepared of the tasks required to reach the stage of production and test the vehicle: detailed engineering, prototype manufacturing and site demonstration. A cost breakdown and a schedule are prepared. The vehicle price for a production rate of 10 vehicles per year is also estimated.

3. AIRPORT RESCUE OPERATIONS

3.1 Crash-Fire-Rescue Protection Service

The primary objective of the Crash-Fire-Rescue (CFR) service is to save lives in the event of an aircraft accident/incident or fire at an airport. This will be accomplished by providing a fire-free escape route for the safe evacuation or rescue of passengers and crew. A secondary objective is to preserve the property involved by containing or extinguishing, where practical, any fire resulting from an aircraft accident or incident.

The objectives of a rescue operation is thus to create conditions in which survival is possible and from which effective rescue operation can succeed.

Specifically, the CFR will normally be the first to arrive at the scene of an aircraft emergency.

3.2 Airport Rescue Requirements

The primary responsibility of the aircraft Crash-Fire-Rescue protection service shall be to respond to an aircraft accident/incident in the areas within the Critical Rescue and Fire-fighting Access Area (CRFAA) and airport boundary; the secondary responsibility shall be to respond to an aircraft accident/incident occuring beyond the CRFAA and airport boundary when it is considered that the crash site is reasonably accessible and a useful service can be rendered.

The operational objective of the Crash-Fire-Rescue service shall be to achieve a response time not exceeding three minutes and preferably not exceeding two minutes when the aircraft accident/incident occurs on the aircraft surface movement area, and as expeditiously as possible to all other accidents/incidents within the CRFAA or airport boundary limits.

Note: Information in this section has been obtained from CATA airport personnel, from Transport Canada, TP3660, Ref. 3 and I.C.A.O. personnel.

The number, type, and characteristics of the vehicles required are based on all of the vehicles having a crash fire-fighting capability and upon such factors as: response time, manpower requirements, number of aircraft exits, fire-fighting techniques, climatic and topographic conditions, and provision of a response capability during short periods of unserviceability. Also, suitable equipment should be available where the area to be covered includes water, swampy areas or other difficult environments that cannot be fully served by the wheeled or ATV vehicles.

3.3 Airport Difficult Terrain and Rescue Vehicles

The type of difficult terrain for which special rescue vehicles may be required includes:

a) the sea or other large bodies of water adjacent to the airport;
b) swamps or other similar surfaces, including the estuaries of tidal rivers;
c) mountainous areas;
d) locations which are subject to heavy seasonal snowfalls.

The types of vehicles available for rescue operations in difficult terrain include: helicopters, air-cushion vehicles, boats, amphibious vehicles and tracked vehicles.

a) Helicopters: the variety of helicopters now in general service offers a range of emergency options, dependent on the capacity, endurance and operational limitations of each type. The cost involved in housing, operating and maintaining a continuously available rescue helicopter may preclude its procurement as an airport facility but arrangements with military or commercial organizations may secure its availability in an emergency.

b) Air-cushion Vehicles: these offer an adaptable form of transport with operational performance, capacity and cost being related to size. The air-cushion vehicle will need a highly-trained operator and skilled maintenance personnel to maximize its operational availability and deployment. The costs of housing, operating and maintaining a hovercraft, which may need a slipway to facilitate its deployment to any tidal water surface, will be substantial. Nevertheless, air-cushion vehicle costs are lower than helicopters having similar payload capacity.

c) Boats: rescue boats selection is dictated by the range of water surface conditions likely to be encountered, the depth of water in the response area, any sub-surface hazard, such as rocks and coral reefs, and then the role to be accorded to each boat. Ice limit their use.

d) Amphibious Vehicles: These are usually wheeled vehicles, relatively small in size and primarily in use by military and security forces. Their speed on water is low and their capacity is limited. All amphibious vehicles would require a launching ramp to facilitate their entry into water as they cannot negotiate significant obstructions.

e) Tracked Vehicles: These can be effective in negotiating rough ground and deep snow but most vehicles of this type have a relatively low pay-load to gross weight factor. A standard tracked vehicle can serve to convey personnel and small items of equipment to the accident site on snow covered surfaces.

The Aerobac vehicle is a new type of vehicle in development. It integrates technologies from tracked and air-cushion vehicles. If its application in difficult terrain proves conclusive it could be the solution to a number of problems confronting the airport rescue services.

3.4 Particular Conditions at Vancouver and Baie-Comeau Airports.

3.4.1 Vancouver

The Vancouver International Airport is situated on an island. The terrain immediately adjacent to the West Dyke of the airport consists of marshy terrain and mudflats for a distance of 3-4 km. It is exposed when the tide is lower than 3 feet and becomes flooded when it reaches 10 feet above datum.

The only successful vehicle with minimum payload capability tried in this area has been the air-cushion vehicle. The major operating and maintenance costs regarding a dedicated hovercraft vehicle has forced the airport authorities to rely on the Canadian Coast Guard (CCG), owner of the hovercraft, to provide the necessary service. However, the CCG hovercraft is not a "dedicated" unit and may not be available at the time of an emergency situation.

3.4.2 Baie-Comeau

During the spring thawing and heavy rainfall periods the western side of the airport, near the privately owned peat moss property, becomes a sodden field. The condition is gradually improving since the

industrial operations of the peat moss property have started and a drainage system has been installed.

Muskeg prevails on the north-west side near the radio tower and the road.

In winter, when the snow cover is more than 45 cm, the only possibility to provide rescue operation outside the runway proper is to use a snow-blower. This is valid if an incident occurs near the runway, otherwise rescue operations would rely on the use of an helicopter. The Québec Provincial Police and Hydro-Québec have each an helicopter in the area which may be affected to the rescue operation if not commissioned elsewhere.

On the south side, a steep slope leads to the St. Lawrence River which flows 12 to 15 m lower than the elevation of the airport. The river is shallow thus making it hazardous for rescue boats.

3.5 General Soil Conditions in Canadian Airports

The terrain conditions described above for Vancouver and Baie-Comeau are representative of difficult terrain types that are encountered in many Canadian airports depending on their location or on the period of the year.

In general, any of the following describes many airport environments across Canada:

a- water surfaces and mudflats;
b- muskeg or marsh;
c- sodded terrain;
d- snow.

4. TERRAIN IDENTIFICATION

4.1 Field Investigation Program

The field investigation program consisted of the following:

a) terrain identification: type of terrain, location of obstacles, i.e. ditches, trees, vegetation etc.

b) cone penetration tests: two types of cones, 30^{o} and 60^{o} apex angle, were driven into the ground. The results were recorded in terms of pressure (kPa) required to advance the cone at 15 cm (= 6.0 in.) intervals, the maximum depth being 1.0 m, whenever possible. The cone tests results were used for soil bearing capacity and trafficability evaluation. Whenever no value was recorded for the cone, resistance actually exceeded 1300-1400 kPa within 2-3 cm depth.

c) Soil sample collection: several disturbed and undisturbed soil samples were collected from each location for laboratory testing.

Previous soil studies conducted by Transport Canada have taken place at the two airports over the years and have been used as references. The soil analysis and borehole tests generally concur with the present study results. (See note).

Twenty locations were tested at various points of the Vancouver International Airport. Drawing 2.

The terrains at the east end of the CRFAA of runway 08-26 are located in the area between the "Russ Baker Way" and the river bank which consists of loose river sand about 0.35 m deep. The land was probably filled with sand dredged from the river.

Note: Details of the soil analysis will be found in the working document No. 1, Appendix C.

The CRFAA of both runways extends beyond the airport boundaries. This occurs at three locations: westerly of runways 08-26 and 12-30 beyond the sea-wall in what is called Sturgeon Bank, and south of runway 12-30, in the Fraser River arm. The Canadian Coast Guard has been helpful in providing its hovercraft vehicle for the identification of these areas. It enabled taking soil samples and performing a cone penetration test in the mudflat area.

Nine locations were tested in the Baie-Comeau airport. The main obstacles (shown on Drawing 3) consisted primarily of two ditches and a wooded area. In all the locations, the 30^0 cone penetration resistances were obtained. Due to the high soil stiffness, only one location could be penetrated to 5 cm depth using the 60^0 cone, while the rest showed resistances exceeding 1,500 kPa on the bared soil (after vegetation was removed).

4.2 Analysis of results

The in-situ and laboratory test results are discussed in this section. Using the cone penetration resistance values and the in-situ soil density, the bearing capacity 'q' is calculated by employing Terzaghi's theory. The bearing capacity of sand using the Dutch-cone (60^0 apex angle, 10 cm^2 base area) penetration test can be computed by using:

$$N_\gamma = q_c/0.80$$

where q_c = cone penetration, kg/cm^2

N_γ = bearing capacity factor (Table 1)

With N_γ one can obtain N_c and N_q from Table 1 to be used subsequently in the equation:

$$q = c\,N_c + \gamma\,D\,N_q + \frac{1}{2}\gamma\,B\,N_\gamma$$

where q = ultimate soil bearing pressure
c = cohesion
D = depth of footing from surface
B = least lateral dimension of footing
γ = unit weight of soil

The above equation is applicable to a continuous footing which should represent the supporting track of the Aerobac, since the length to width ratio for the track is about 4.

For cohesive soils, the undrained shear strength, S_u, may be obtained from cone penetration values as (Ref 4):

$$S_u = (q_c + \gamma D)/N_f$$

where N_f = bearing capacity factor ranging from 5 to 70.

For cohesive soils $N_q = 1.0$ and $N_\gamma = 0$, the bearing capacity equation becomes:

$$q = cN_c + \gamma D$$

Substituting S_u for c and using $N_c = 5.7$

$$q = 5.7\ S_u + \gamma D$$

N_γ	N_c	N_q	N'_c	N'_q	N'_γ
0.0	5.7	1.0	5.7	1.0	0.0
0.5	7.3	1.6	6.7	1.4	0.2
1.2	9.6	2.7	8.0	1.9	0.5
2.5	12.9	4.4	9.7	2.7	0.9
5.0	17.7	7.4	11.8	3.9	1.7
9.7	25.1	12.7	14.8	5.6	3.2
19.7	37.2	22.5	19.0	8.3	5.7
35.0	52.6	36.5	23.7	11.7	9.0
42.4	57.8	41.4	25.2	12.6	10.1
100.4	95.7	81.3	34.9	20.5	18.8
297.5	172.3	173.3	51.2	35.1	37.7
780.1	258.3	287.9	66.8	50.5	60.4
1,153.2	347.5	415.1	81.3	65.6	87.1

Table 1 Bearing Capacity Factors for Use in Equations for General Shear Conditions N_c, N_q, N_γ, and Local Shear conditions N'_c, N'_q, N'_γ (Ref 4).

4.2.1 Vancouver International Airport (Drawings 1 and 2)

Combining the in-situ tests, done between May 30, and June 3, 1983, and laboratory test results, the following observations can be made:

(a) The soil can be classified as ML or MH as can be seen in Table 4.1 and Figure 1, according to the Unified Soil Classification system, i.e. inorganic silty or clayey sand of lower (ML) and higher (MH) plasticity. In a few locations the soil was silty sand of very low plasticity.

(b) The in-situ water content varies between 20% and 50% for most of the locations tested, with the exception of those where non-plastic sandy soil was found. However, water contents up to 70% are possible during the winter season which is the peak precipitation season (Table 4.2)

(c) The in-situ soil bulk density varies between 1.65 gr/cc and 2.0 gr/cc at about 15 cm depth.

(d) The cone resistance range at 15 cm depth is:

400 kPa to 1400 kPa for the 30^{o} cone
400 kPa to over 1400 kPa for the 60^{o} cone.

Although the 60^{o} cone provides more resistance than the 30^{o} cone due to base area difference, it is not uncommon to find that for the same soil, the 60^{o} cone may show less resistance. This might be due to the cone configuration since once the 60^{o} cone is penetrated, the soil is not totally in contact with the rod. Unlike in the 30^{o} cone case, the rod is in contact with the soil, thereby providing more resistance due to rod-soil adhesion.

(e) The soil bearing capacity was calculated using the method described earlier in this section. The worst condition was represented by using the lowest 60^{o} cone resistance obtained in conjunction with the lowest density value. The low cone value was obtained in a very wet area, where shallow water ponding had occurred. Similar conditions might prevail during the winter months when the amount of precipitation is at its highest level. Three worst conditions taken from the cone resistance histogram in Figure 1 are considered hereafter in Table 2 for two bearing capacity factors N_{f_1} and N_{f_2}:

	Case 'A'	Case 'B'	Case 'C'
60^{o} cone resistance	400 kPa	200 kPa	100 kPa
In-situ density	1.66 gr/cc	1.66 gr/cc	1.66 gr/cc
Depth below surface	0.33 m	0.45 m	0.6 m
Track width	1.00 m	1.00 m	1.00 m
N_c	5.7	5.7	5.7
N_{f_1}	16	16	16
c_1	25.0 kPa	11.8 kPa	6.2 kPa
Ultimate bearing pressure, q	142.8 kPa	73.3 kPa	36.6 kPa
N_{f_2}	20	20	20
c_2	20.0 kPa	9.4 kPa	5.0 kPa
Ultimate bearing pressure, q	114.5 kPa	59.9 kPa	30.0 kPa

Table 2 Soil Bearing Capacity under Worst Conditions for Vancouver

The locations where sandy soil was encountered show relatively high cone resistance such that the 60^{o} cone could not penetrate through the soil. Hence, these are not problem areas.

The cone penetration tests (60^{o} cone) performed outside of the airport perimeter in front of the sea wall, which was composed of sludge and fine sand, showed resistances of 100 kPa and 400 kPa at 15 cm and 30 cm depth respectively. The density of the material was not measured because it was not possible to obtain an undisturbed sample. Hence, no calculation of bearing pressure was attempted.

If a submerged condition should exist (i.e. the water table rised to the ground surface), the submerged unit weight should be used in the calculations as 1.66-1.00 = 0.66 gr/cc. The ultimate bearing pressure q is shown in Table 3.

	Case 'A'	Case 'B'	Case 'C'
N_{f_1}	16	16	16
c	24.4 kPa	12.1 kPa	6.0 kPa
q	141.2 kPa	70.6 kPa	36.3 kPa
N_{f_2}	20	20	20
c	19.5 kPa	9.7 kPa	4.8 kPa
q	113.3 kPa	57.1 kPa	29.5 kPa

Table 3 Soil Bearing Capacity under Submerged Condition for Vancouver

While Case 'C' indicated low ultimate bearing pressure, the contact pressure imposed on the ground by the AEROBAC can be decreased by engaging the air-cushion.

4.2.2 Baie Comeau Airport (Drawing 3)

The in-situ tests done between June 15 and 17, 1983, and laboratory investigation reveal the following:

a) The soil can be classified as SP or SP-SM (Table 4.3) according to the Unified Soil Classification system, i.e. poorly-graded sand to sand silt mixture with a small amount of fines.

b) The water content varies from 3.5% to 26% with most values between 5 and 15%. The meteorological data (Fig. 2) indicate that the average precipitation, about 80 mm of rain, is quite high for the month of July. However, it should be noted that while the snow period was longer this year (snow and ice melted completely by end of May), the first two weeks of June were relatively sunny and dry. Soil water content data previously obtained by the airport authorities show that a water content of 5-15% is typical for the month of June, while slightly higher water content, in the order of 10-30%, may be obtained in the months of July to September.

c) The in-situ density varies from 1.57 gr/cc to 1.90 gr/cc. It should be noted that these data were obtained from 15 cm to 30 cm depth (typical sample height = 15 cm).

d) The cone resistance range is:

500 kPa to 1400 kPa for the 30^{o} cone
1000 kPa to 1500+ kPa for the 60^{o} cone

Actually, in almost all of the sites tested, the 60^{o} cone could not be advanced into the soil due to the high soil resistance.

e) The bearing capacity of the soil was calculated using the method discussed previously in this section for sandy soils. To represent the worst possible conditions, two bearing capacities were assumed. (Table 4).

	Case 'A'	Case 'B'
60^{o} cone resistance	1000 kPa	1000 kPa
In-situ density	1.57 gr/cc	1.57 gr/cc
Depth below surface	0.33 m	0.33 m
Track width	1.00 m	1.00 m
N_{γ}	12.74	12.74
N_{q}	15.6	15.6
q, Ultimate bearing capacity	37.3 kPa	103.1 kPa

Table 4 Soil Bearing Capacity under Worst Conditions at Baie-Comeau

No cohesion had been assumed in either of the two cases, (i.e. c = 0).

A histogram of the 30^{o} and 60^{o} cone penetration resistance values appears in Figure 1, for the cases investigated in both airports.

4.3 Discussion and Evaluation

4.3.1 Vancouver International Airport

Nearly all the areas in the vicinity of the runways are composed of compacted silty or clayey soil of low to medium plasticity; they are well drained and covered with grass which prevents ponding during heavy rainfall. The area off the west end of both runways and up to the sea-wall dyke has several non-vegetated spots resulting in softer material. The location which is composed of sandy material appears to be very well compacted.

The main problem at the Vancouver International Airport is the region extending beyond and west of the sea-wall outside the airport perimeter. During high tide, the water reaches close to the dyke. Some of the area next to the dyke is vegetated (approach to runway 08-26), indicating that the tide does not normally cover all the ground around the dyke. However, this vegetated area is full of trenches and ditches which usually contain water even under low tide conditions. The vegetated terrain is hard but the soil in the ditches is very soft and in a muddy condition. The ditches may be 1 to 1.5 m deep and/or wide, mostly filled up with mud. Beyond this area, the beach sand is exposed under low tide conditions which could be trafficable. At the runway 12-30 west approach, the situation is different. The sea bottom is covered with a very soft suldge mixture which may attain more than 1 m depth in some areas.

4.3.2 Baie-Comeau Airport

The type of soil found to exist in the area examined presents no serious problem from the bearing capacity point of view. A problem area exists at the west end of the single runway, though outside the 1 km limit. Soft soil of a depth up to 5 m is presently being excavated by a private entreprise and sold as fertilizer. This soil consists of thick decomposed plant roots and could be classified as a type of muskeg.

As it is noted on Drawing 3, thick vegetation at certain areas would prevent vehicle mobility. In addition, vehicle exit to the roadway in the east end of the runway is impossible due to vegetation (trees). This restriction applies to all CFR vehicles.

Other problems include the steep slope off the river bank on the east side of the runway as well as the tide. The steep bank does not allow vehicle access to the river beach. When the tide is at its lowest, access by boat is not possible.

In winter, the airport authorities do not normally clear the snow beyond the taxiways and the runway. As a result, snow banks of 1.0 to 1.2 m are found in the area next to the runway.

5. ANALYTICAL EVALUATION OF RUNNING SPEED

This section of the report is a summary of an analytical study * conducted to evaluate the performance of two vehicles, the candidate vehicle Aerobac AB-7 and the reference vehicle, Foremost Delta Three B-4S on two sites - Vancouver and Baie-Comeau airports. The general objective is to determine representative minimum travel times between the fire hall of the airports and the point of an eventual airplane crash along certain straight path lengths. The intent of the exercise is to provide an appreciation of the minimal time frame to implement quick assistance for rescue operations. For purposes of the study, it was assumed that any crash would occur in an area bounded by lines located 150 m on both sides of the centerline of each of the runways and 1,000 m from their end points.

A separate set of computations deal with runs on muskeg and snow which are meant to be located anywhere outside the above referred Critical Rescue and Fire-Fighting Access Area. These runs simulate applications that can take place either within or outside the airport boundaries, which in this latter case, are representative of other than airport uses of the Aerobac.

An analysis is made of the performance of both vehicles on fine-grained, coarse-grained, mudflat, muskeg and snow surfaces.

The analytical study was performed using a complex off-road mobility (dynamic computer) program, the Nato Reference Mobility Model (NRMM), which is designed to simulate the cross-country movement of vehicles** This complex interactive computer program requires, as input, specific vehicle (technical) characteristics and information about terrain conditions, each of which are discussed in the following sections.

5.1 Terrain Data Requirements

The general survey carried out at the Vancouver and Baie-Comeau airports provides terrain data for input in the NRMM program. In addition, the survey allows identification of which factors would be relevant in predicting the mobility of the two vehicles. The results from the field study indicate that three main site characteristics appear to be most important:

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* See appendix C No. 2

** The NRMM is a complex interactive dynamic (computer) program which is used as a reference program for evaluation of vehicle mobility performance under specified terrain conditions. It was developed initially in the early 1970 period by the U.S. Army and is used to perform initial scrutiny of candidate vehicles. (Ref. 5).

1) type of soil
2) strength of soil
3) topographic slope

5.1.1 Type of Soil

For the purpose of running the program the soil near the surface (i.e. surface layer soil, depth up to approximately 40 cm) must be classified as follows: fine-grained soil, coarse-grained soil and muskeg.

From the results of the geotechnical report it appears that the soil in the Vancouver airport area is predominantly fine-grained, except for the area known as Sturgeon Bank and the area surrounding the high intensity lighting spit, west of the approach to runway 08-26. These areas consist mainly of mud, sludge and grass and are partially or completely flooded by sea water depending on the tidal condition. The areas are modelled in the analysis by using a variable "NSLIP" which allows the analysis to take into account the loss of strength and slip effects depending on the degree of surface moisture.

The Baie-Comeau airport consists mainly of coarse-grained soil, which in the winter is covered by snow. In the analysis performed herein, the snow* was assumed to have the following properties:

Snow depth	= 1.1 m
Density	= 0.2 gr/cm^3
Angle of friction	= 21^o
Cohesion	= 3.51 gr/cm^2

5.1.2 Strength of soil

The NRMM program requires, as input of soil strength, a quantity referred to as cone index. The range of readings from a 3.23 sq. cm (0.5 sq. in.) cone penetrometer is from 0 to 300. In order to facilitate soil classification in the field, the values of cone index are divided into specific ranges or classes which are as follows:

Class No.	Class Range of Cone Index	Value Selected for Prediction
1	280	300
2	221 - 280	250
3	161 - 220	190
4	101 - 160	130
5	61 - 100	80
6	41 - 60	50

* The density of snow is generally given in terms of gr/cm^3. The density of a "normal" snow pack varies from 0.2 to 0.5 depending on depth and age.

The value selected for a prediction is the actual value of cone index used by the program which assumes it to be representative of the class which contains it.

At both Vancouver and Baie-Comeau a series of locations were selected for making cone penetrometer tests. Class numbers of cone index were then assigned to each test location.

Considerable effort was devoted to improving the modelling of the very low strength mudflat/sludge terrain found in Vancouver to be used in the NRMM computer program. Essentially, the problem consisted of modifying the program in order to allow smaller values of cone index used to describe soil strength. Furthermore, an analysis of the performance of the Aerobac AB-7 and the Foremost on muskeg needed also requires to modify the program for the same reason.

5.1.3 Topographic Slope

Topographic slope at various points for the two sites was evaluated with the aid of contour maps. Slope information for the program input is also done using classes associated with typical ranges of slopes:

Class No.	Class Range of Slope (%)	Value Selected for Prediction (%)
1.	0 - 2	1
2	2.1 - 5	3.5
3	5.1 - 10	7.5
4	10.1 - 20	15.0
5	20.1 - 40	30.0
6	40.1 - 60	50.0
7	60.1 - 70	65.0
8	70 -	72.0

The great majority of the slope numbers is found to be in class number 1.

Once this information is processed, maps showing the sites divided into "terrain units" can be constructed. A terrain unit is defined as an area which can be described by a specific combination of the three terrain elements described above (i.e., soil type, strength and slope). These maps are then used for route selection as explained later.

5.2 Vehicle Technical Characteristics - Aerobac

5.2.1 Aerobac AB-7

The performance calculation of the vehicle does in part depend on the mathematical simulation of the air-cushion and traction mechanical systems interaction.

Some of the power is absorbed by the fans of the air-cushion system and thus the available power for the track system is decreased. However, the transmission system is such that the relationship between the torque delivered to the sprockets and the engine speed can be changed by the use of a hydrostatic pump in the transmission system. In the analysis, several simplifying assumptions had to be made to render the system compatible with the computer program requirements.

5.2.2 Air-Cushion-Tracks Interaction - Power Effects

It is obvious that as the air-cushion pressure changes, the torque-speed relationship at the transmission also changes since some power is diverted to the fans. Since the computer program used for the analysis cannot analyse this system as is, the following assumption was made: the power available for driving the tracks at any speed is proportionally dependent on the percentage of power required for generating the pressure in the air-cushion. In other words, if P_f is the percent power required for the fans at a given air-cushion pressure, then the power remaining available for the tracks P_t is simply:

$$P_t = 100 - P_f$$

A. 100% Loads on Tracks

When the air-cushion is not being used, the engine torque-speed relationship is taken directly from the manufacturer's performance engine chart coupled with a torque converter.

B. 72.5% or 27.5% Load on Tracks

In the previous feasibility report, it was reported that when the percent weight supported by the tracks was 72.5% or 27.5%, the fan power required was 30 kw and 125 kw, respectively. Therefore, the engine-torque speed was calculated proportionally to obtain the power available at the tracks.

5.2.3 Air-Cushion-Tracks Interaction - Load Distribution Effects.

The contact pressure between the tracks and the soil can be varied as required by soil conditions. In order to correctly model this situation the variable gross weight was made proportional to the three selected percentages of load on tracks: 100%, 72.5%, 27.5%.

5.2.4 Aerobac Vehicle Characteristics (NATO NRMM)

The following is a list of the vehicle input data (in alphabetical order) as required by the mobility program. See Appendix A.

- Effective Area of Track
  The track being thicker in the middle of the track, the effective track shoe area is taken as half the track surface. This is to take into account that the track may not be 100% in contact with the soil due to its variable thickness.
- Loaded horizontal distance from the center of gravity to the centreline of the rearmost assembly of prime mover.
  This distance is measured from the centre of gravity of the vehicle to the last road wheel.
- Displacement of engine.
- Number of points to describe the engine torque-speed relationship.
- Engine torque-speed relationship.
  The above two variables describe the engine torque-speed relationship and therefore change as the air-cushion pressure or percent load on tracks is varied.
- Combined final drive gear ratio
  This is actually the combined final drive-differential gear ratio. This number is the total reduction between the transmission and the driving sprockets.
- Final drive efficiency.
- Track grouser height of track assembly.
- Net engine horsepower (HP): 100%, 72.5%, 27.5%.
- Two-cycle diesel engine.
- Total number of running gear assemblies.
  The vehicle is equipped with one set of driving sprockets.
- Number of cylinders per engine.
- Flexible track assembly.
- Number of transmission gear ratios.
- Number of road wheels on track assembly.
- Maximum torque produced by the engine at 100%, 72.5% and 27.5%.
- Revolutions per km of driving sprocket.
- Total track thickness + bogie rolling radius.
- Track length.
  This value is usually taken as the distance from the centerlines from the first to the last road wheels.
- Track width.
- Transmission gear ratio and efficiency.
- Maximum width of vehicle.
- Weight of vehicle.
- Maximum vehicle braking coefficient in kg/kg of load carried.

5.3 Vehicle Technical Characteristics - Foremost Delta Three B-4S

The Foremost Delta Three B-4S is used as an all terrain wheeled fire-fighting vehicle whose performance in natural terrain is also investigated in this study. Unlike the Aerobac, this vehicle has already

been built so that vehicle specifications were readily available. A copy of the information from which the vehicle data file was constructed for running the program is included in Appendix B of this report.

5.3.1 Foremost Delta Three B-4S Vehicle Characteristics (NATO NRMM)

The following is a list of the vehicle input data (in alphabetical order) as required by the mobility program.

- Distance from running gear assembly to next assembly (inter-axle distance).
- Loaded horizontal distance from CG to centreline of rearmost assembly of prime mover.
- Displacement of each engine.
- Minimum ground clearance of combination.
- Deflection of each tire under load at the pressure specified for fine-grained soil, coarse-grained soil and highway, all three of which were assumed to be 1.41 kg/cm^2.
  No information about tire stiffness was given so that the deflection of each tire under its share of the total load was assumed to be 10% of the original undeflected radius.
- Outside wheel diameter of unloaded tires.
- Number of points to describe the engine torque-speed relationship.
- Height of driver's eyes above ground.
- Combined final drive gear ratio (differential) and final reduction.
- Final drive efficiency.
- Net engine power.
- Measure tractive effort and power train data.
- Bias type tires.
- Single wheels.
- Two cycle diesel engine.
- Mechanical transmission with no locking differential.
- Number of running gear assemblies.
- Number of cylinders per engine
- Number of engines.
- Number of transmission gear ratios.
- Number of tires.
- Number of points to describe the tractive effort vs speed relationship.
- Speed and tractive effort component of the tractive effort vs speed curve.
- Tractive effort.
- Maximum torque produced by the engine.
- Rim diameter of wheel.
- Revolutions/km of tire element, assuming rolling radius to be 90% of the undeflected radius.
- Wheel rim width.
  This information was not available, therefore the rim width was taken to be equal to the width of the tires.
- Section height of tires.

- Section width of tires.
- Distance from front of first running gear assembly to rear of last.
- Tire ply rating.
- Tire inflation pressure: assumed as 1.41 kg/cm^2.
- Transmission gear ratio and efficiency.
- Weight on running gear.
- Maximum combination braking coefficient assembly in kg/kg of load carried.

5.4 Performance of Aerobac and Foremost Vehicles

The performance of the Aerobac and Foremost vehicles on fine-grained soil is shown schematically in terms of speed up grade vs slope * relationship for soil cone index values ranging from class 1 to class 6, Figure 3. The two vehicles perform more or less equally for very mild slopes, both being able to reach a speed of 48.3 km/h. For steeper slopes, however, the Aerobac seems to be superior due mainly to its capability of varying the track-ground contact pressure with the air-cushion system.

The effect of air-cushion pressure, for the Aerobac, expressed in terms of percent load of total weight supported by the tracks, is shown in Figure 4. It is seen that for both class 1 and class 6 strength soil, the performance improves with decreasing percent load on tracks with highest attainable speeds at 27.5% load on tracks. It should be pointed out at this point, that on graphs comparing the performances of both vehicles, (such as Figure 3), the relationship used to represent the Aerobac is based on the best results obtained among the three levels of track-ground contact pressure.

The upgrade speeds vs slope relationships for coarse-grained soil are shown in Figure 5 and again the Aerobac seems to perform better than the Foremost. The main difference from the case of fine-grained soil is that the attainable speed of the Aerobac is 48.3 km/h on slopes of up to approximately 8% whereas that of the Foremost on a very mild slope of 1% is only about 30 km/h (on soil of class 1 strength). In addition, the Aerobac seems to be less sensitive to change in soil strength than the Foremost, as shown in Figure 5, where the band, whose boundaries represent speed-slope relationships for soil strengths class 1 and class 6, is much narrower for the Aerobac than for the Foremost vehicle. The same pattern exists for fine-grained soil (Figure 3).

The effect of air-cushion pressure on the performance of the Aerobac on coarse-grained soils is illustrated in Figure 6. It is again observed that as for fine-grained soils, increasing the air-cushion pressure improves the efficiency of the vehicle.

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* Slope climbing speed achievability is an indication of pull traction and acceleration capability.

For the mudflat terrain, a speed vs soil strength relationship was judged to be of great interest. Numerical instability caused problems when trying to run the program with low values of cone index. Nevertheless, it was possible to obtain a relationship between speed and cone index values ranging from 5 to 36 for slopes smaller than 2%. The results are shown in Figure 7. It is quite obvious that the air-cushion system is a great advantage for the Aerobac whose performance on the mudflats is seen to be very much superior to that of the Foremost. Moreover, it is believed that the actual cone index value for this type of surface is definitely lower than 14 which is the limit value of soil strength for which the Foremost is able to have some mobility. On the other hand, the Aerobac, according to Figure 7, is able to operate for cone index values as small as 5 and probably lower when the air-cushion pressure is further increased. The Aerobac is therefore definitely more efficient on this type of terrain.

This efficiency depends on the load carried by the air-cushion as shown in Figure 8. With cone index value below 5, the Aerobac will use increasing air-cushion pressure thus relieving drag induced by the tracks. When the tracks do not carry any load, propulsion is provided by the reaction of water entrained by the tracks. Speed in this condition would not exceed 10 km/h, this corresponding to the appearence of the first wave drag peak, at a Froude of 0.3, (Ref. 6).

The results of the analysis of the performance on muskeg are shown in Figure 9, again in terms of a speed vs cone index relationship for slopes of 0-2%. It is seen that the Aerobac and Foremost vehicles operate with approximately the same efficiency for cone index values greater than about 125. At lower values, the performance of the Aerobac is considerably better. The relationship shown in Figure 9 corresponds to the case of the track supporting 100% of the total weight (i.e. the air-cushion system inoperative). Results for percent load on tracks of 72.5% and 27.5% are not available. It is however, believed that just as for the case of mudflat terrain, increasing the air-cushion pressure is likely to further increase the speed capability of the Aerobac. Therefore, it can be concluded that once again the Aerobac seems to be superior to the Foremost especially if one considers that the cone index values of muskeg near the Baie-Comeau airport may not be too dissimilar to those measured in Schefferville (measured in a recent field trip) and which ranged from 30 to 120.

Finally, the performance on snow is presented graphically in Figure 10. The computer analysis shows that the Foremost could not operate at all in snow. The Aerobac was analysed for the 100 and 27.5 percent track loading conditions, a summary of which is given schematically in Figure 11. Again, an increase in air-cushion pressure increases the efficiency of the vehicle. The maximum speed obtained (for Class 1 slopes, 0-2%) is about 42 km/h.

5.5 Route selection Procedure

The route selection between two points A and B on a given map is done by selecting the path which will make the total travel time minimum. This is done by the following trial and error procedure.

The first step is to divide the map into terrain units which can be said to be uniform in terms of factors which can affect the speed of a given vehicle within the unit. As mentioned, these factors are soil type and strength, topographic slope, obstacles, surface roughness, vegetation, etc. During the field investigation at the two airports, it was concluded that the surface roughness and vegetation were negligible speed limiting factors, so that the performance of a given vehicle would be influenced only by soil type, strength, slope and ditches. In all cases, it was also observed that these ditches should be considered unaccessible areas to the two vehicles in question so that these areas should be avoided by the vehicles.

The second step is to assign the "up" (V_u) and "down" (V_d) speeds, which are the attainable speeds, as calculated by the program, while travelling up and down a given slope on terrain of a given type and strength, to each terrain unit. Once this is done, the trafficability of the area under study is known.

The third step is to draw trail routes from A to B, carefully avoiding unaccessible areas, such as ditches, and to compute the total travel time. See Figure 12.

In the case where a terrain unit is represented by a mound or a trench, on which the vehicle may have to travel upgrade and then downgrade, the travel time, t_i, within a given terrain unit is computed as:

$$t_i = 2d/(V_{u_i} + V_{d_i})$$

where d_i = travelling distance in terrain unit 1

V_{u_i}, V_{d_i} = upgrade and downgrade speeds for terrain unit.

In this equation, it is assumed that when crossing such a terrain unit, half the distance is travelled upgrade and half downgrade.

In ordinary terrain units, where the slope is constant, the travelling time is computed as:

$t_i = d_i/V_{u_i}$ or $t_i = d_i/V_i$, depending on whether the vehicle is travelling upgrade or downgrade.

The total travel time for a particular route, $T_{A,B}$, between points A and B is then computed as the summation of the travelling times of the terrain units which are on the route between A and B.

5.6 Comparative Travelling Time

In this section, the comparative travel time for selected routes for Vancouver and Baie-Comeau airports are computed for both vehicles. The routes selected represent straight line traverse to point-of-crash - i.e. routes are examined - straight line over whatever terrain, and choice of route over runway. In the case of the Aerobac, the maximum attainable speed (dependent on the air-cushion pressure) for a given power system, is used in calculating the travel time. It should also be noted that in the case of the given route crossing a runway, taxiway or road, it is assumed that the vehicle speed will not change for the terrain unit in which the vehicle is travelling. However, if the vehicle is actually travelling along a paved surface, then the speed is assumed to be the maximum design speed provided no steep slopes are encountered.

The following is a summary of the results detailed in Appendix D.

5.6.1 Vancouver Airport

End "A"

Best route: V-A1
Travel time, Aerobac: 5.5 min
Travel time, Foremost: Cannot travel on mudflat

End "B"

Best route: V-B1
Travel time, Aerobac: 2.0 min
Travel time, Foremost: 2.0 min

End "C"

Best route: V-C1
Travel time, Aerobac: 2.6 min
Travel time, Foremost: 2.6 min

End "D"

Best route: V-D1
Travel time, Aerobac: 4.0 min
Travel time, Foremost: 4.0 min

5.6.2 Baie-Comeau Airport

End "A" - normal season

Best route: B-A1 (Aerobac), B-A2 (Foremost)
Travel time, Aerobac: 2.9 min
Travel time, Foremost: 4.0 min

End "B" - normal season

Best route: B-B1 (Aerobac), B-B2 (Foremost)
Travel time, Aerobac: 1.9 min
Travel time, Foremost: 3.3 min

End "A" - snow-covered terrain

Best route: B-A1
Travel time, Aerobac: 3.3 min
Travel time, Foremost: cannot travel in snow

End "B" - snow-covered terrain

Best route: B-B1
Travel time, Aerobac: 2.2 min
Travel time, Foremost: cannot travel in snow

In summary, the Aerobac remains mobile and can obtain a reasonable response time in mudflat (Vancouver) and in deep snow (Baie-Comeau) where the Foremost is immobilized. The Aerobac remains superior to the Foremost in marginal terrains (muskeg). This efficiency depends highly on the air-cushion system which is used to relieve the track bearing pressure. When routes cross solid grounds, both vehicles have similar travel times.

6. RESCUE EQUIPMENT

The study determined if a standard fire-fighting equipment equal in capacity to the 4500 ℓ/540ℓ water and foam system presently in service on a wheeled all terrain vehicle can be installed on the deck of the Aerobac. All major airports have such fire-fighting wheeled vehicles.

Data on the equipment was obtained from three specialized Canadian manufacturers: Walter Canada Inc., Pierre Thibault Trucks Inc. and CDN Research and Development Ltd.

The main equipment required consists of a water tank, liquid chemical tank, centrifugal pump capable of discharging 2,650 lpm at 1,380 kPa (200 psi) pressure, valves, piping, variable position turret and electro-hydraulic single remote control. The specified reach of stream is 60 m. Control of the pump, turret functions and auxiliary system is to be located in the cab adjacent to the driver who must be able to drive the vehicle and attack the fire simultaneously.

The specifications, dimensions, capacities and weights of each system were studied and analysed. It is in fact possible to properly fit all the needed equipment on the Aerobac. The water tank can be centered on the center of gravity of the vehicle, its longitudinal axis coinciding with the one of the Aerobac. This will ascertain the stability of the vehicle when the air-cushion system will be in operation. The foam tank, accessories, piping and turret can all be mounted easily and conveniently. The centrifugal pump can be located under the water tank.

There is also provision to fit an auxiliary system which consists of a front sweep nozzle to protect the skirt, an undercarriage nozzle and a side reel mounted 32 mm diameter hose.

6.1 Estimated Weights

The estimated weights are as follows:

4,500 ℓ net capacity, plus 3% safety margin	4,635 Kg
540 ℓ liquid chemical	540
Water tank	730
Liquid chemical tank	75
Pump	185
Piping, valves, turret, accessories	400
Sub total	6,565 Kg
Auxiliary system	160
Total	6,725 Kg

Table 5 Fire-Fighting Equipment Weights

The 3% water safety margin is a regulation. The total weight is slightly under the 7,000 kg pay load capacity specified in the technical feasibility study dated March 1982, Report TP3507F. However, the practice on water tankage is to allow for residual water. The amount ranges around 450 ℓ thus adding 450 kg of weight for a total of 7,355 kg, including the auxiliary system. The extra weight is small and may be coped with if necessary by designing a water tank that would reduce or eliminate completely the estimated amount of 450 kg of residual water remaining at the bottom of the tank. Any small additional weight would not hinder the operation of the vehicle hovercraft function since there is increased engine power compared to the previous technical feasibility study. A fire-fighting equipment enclosure is not included in the above weights nor a heater to prevent the liquid from freezing in winter. The enclosure would be made of aluminium and weigh around 150-175 kg.

Fiberglass or aluminium is the specified material for the water tank and fiberglass or stainless steel for the foam tank. It is assumed that standard products will be used throughout. This is the case for the fire pump manufactured in Canada by Pierre Thibault Inc. and which can be slightly modified for the application

6.2 Fire-Fighting Hydraulic Pump and Motor

The centrifugal fire pump requires approximately 150 HP to operate at full capacity. It will be driven by a hydrostatic transmission similar to those selected for the traction and the fans of the Aerobac. The required models are the following:

Sundstrand motor, model MF-21
Sundstrand pump, model PV-25

7. TRANSPORTATION COSTS

Door to door transportation costs have been estimated between Montréal which was taken as the origin and the two airports. Road, rail and water modes were evaluated. The following are the dimensions and weights used.

- Vehicle less Skirt, Tracks and Wheels

  Length 11 m Width 4.1 m* Height 2.8 m

- Tare weight. Fuel, hydraulic oil, water and liquid chemical tanks are empty. The skirt, tracks and wheels must be shipped in separate crates to cope with transportation clearances.

Aerobac, less tracks and wheels	10,700 kg
Fire fighting equipment	1,700 kg
	12,400 kg
Tracks and wheels	4,300 kg
Total	16,700 kg

7.1 Vancouver

Railway is most economical mode. The rate is based on an off highway vehicle classification and on 13,640 kg minimum. Delivery time from plant to site is estimated at a minimum of 2 weeks.

Vehicle, less Tracks and Wheels

- Hauling to railway yard on drop deck semi-trailer	$ 520
- Loading and securing on flat car** 45 t crane plus crew of riggers	1,600
- Transportation to Vancouver: 12,400 kg X $32.91/100 kg	4,080
- Off-loading and reloading on drop deck semi-trailer***	1,200
- Hauling to site	520
	$7,920

Tracks and Wheels

Loaded on same flat car: 4,300 kg X $32.91/100 kg	$1,415
The total cost for the complete vehicle is	$9,335

In comparison, road transportation would cost $12,300 due to the overwidth dimension.

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* oversize dimension but within clearance of regular routing

** CN car serial # 665000-499

*** takes less time than loading and securing and does not require any material supply.

7.2 Baie Comeau

Trucking is most economical mode. Routing is by Chicoutimi. The body of the Aerobac and the tracks and wheels crated separately can be loaded on one drop deck semi-trailer. Delivery time is estimated at 5 days.

Price based on 18,200 kg including permit and escort $2,600.

Movement by rail is prohibitive due to the high cost of hauling the Aerobac to and from the railway yard and blocking. Shipping cost from the port of Montréal including hauling to and from each harbor would cost $5,400. However, water movement would eliminate skirt and tracks removal and reassembly in the field afterwards. The saving gained should be evaluated before deciding between the trucking or marine mode.

8. ENGINEERING REVIEW, PROCUREMENT COST AND SCHEDULE

This section makes a review of the engineering aspects of the Aerobac AB-7 as referred to in the feasibility report TP3507F. It also up-dates the fabrication cost estimates and schedule for the fabrication of a prototype and 10 production units.

8.1 Engineering Review

8.1.1 Power Train

The concept of the previous design limited the maximum speed to 30 km/hr, which is insufficient with respect to an expected response time in an airport emergency situation. The present application changes the power supply and gear ratio to reach 60 km/hr when travelling on solid ground, i.e. areas adjacent to airport runways.

The mechanical changes are listed below:

- The 8V-92TA Detroit Diesel engine is replaced by a 12V-71T model. The engine is relocated at the back of the vehicle to give a better load distribution.

- The gear train ratio is changed. The required calculated value is 6.03. It is recommended to choose a differential ratio of 6.1. This eliminates the need for final drive speed reducers, costs less and saves weight. A torque converter and lock-up device are added to the six speed Clark transmission, model 28661.

Power required at 60 km/hr on hard gravel road and gross weight of 22,525 kg and without air-cushion = 491 HP (365 kW). Torque = 7,535 N.m.

The 12V-71T engine develops 553 BHP (413kW) at 2100 RPM. The power needed for the auxiliary engine accessories is estimated at 25 kW. The available net value then becomes 388 kW.

8.1.2 Mechanical Traction and Suspension

The muskeg type and snow type tracks, for winter, are chosen but it is recommended to replace the hydraulic suspension by hydro pneumatic suspension controlled from the cab.

The driving sprockets are moved from the back to the front to reduce the possibility of disengagement of the tracks. They are driven by a Sundstrand hydraulic motor MF-36 and pump PV-24.

8.1.3 Fuel Tanks

The application of the Aerobac as an airport emergency vehicle implies short runs. The fuel tanks for the application described in the previous feasibility study allowed to carry 810 ℓ of fuel with an autonomy of 13 hours. To save weight, the capacity is reduced to 200 ℓ giving over 3 hours of operation.

8.1.4 Air-Cushion System

The French firm Sedam had written in the feasibility study report TP3507F that an advantage would be gained if the speed of the fans could be varied independently of the speed of the main engine. A hydraulic power system has been incorporated in the design. It gives the operator the control over the power distribution to the fans and tracks, depending on the nature of the terrain conditions. The required equipment is the following:

Sundstrand hydraulic motor, model MF-24
Sundstrand pump, model PV-25

It is recommended to use aluminium fans which will reduce the weight by 300 kg.

The Aerobac will carry a total water and chemical payload of approximately 5,400kg. It is envisaged that the full use of the air-cushion sustentation system will be required when difficult terrain conditions will prevail along part of the way to reach the site of an aircraft on fire. Under these conditions the center of gravity of the total vehicle mass must remain within a tolerance of 1%. The payload being 25% of the total mass, it needs to be distributed over as large an area as possible which will thus minimize the bending stresses in the caisson.

8.1.5 Total Power Requirements

The total power requirements have been estimated for different operating conditions:

100% on tracks; 60 km/hr	365 kW
27.5% on tracks; fire-fighting equipment; 10 km/hr	306 kW
100% on air-cushion; fire-fighting equipment	302 kW
27.5% on tracks; 60 km/hr	272 kW
100% on air-cushion; vehicle standing still	190 kW
100% on tracks; fire-fighting equipment; 10 km/hr	173 kW

The available net power (388 kW) from the engine is thus sufficient for the selected operating conditions.

8.2 Prototype Procurement

There are a certain number of activities required to bring the Aerobac from the engineering feasibility study level to an actual operational, tested, demonstrated and fully operational vehicle.

In this section the technical development activities and associated costs and schedule are discussed.

The activities have been broken into three phases:
Phase I: Engineering and prototype manufacturing plans and specifications
Phase II: Manufacturing of prototype
Phase III: Demonstration and vehicle improvements.

One must not forget that this is a development project of a new vehicle. The costs and schedule estimates take into consideration what could be considered as a "normal" level of development problems.

The overall project costs and schedule provided herein are considered realistic unless unforeseen major problems come up.

Phase I: Engineering, Manufacturing drawings and Specifications:

This is the first concrete step following the theoritical technical work performed to this date. It would provide a complete detailed list of all the elements composing the vehicle with all the needed vehicle drawings and the manufacturing plans, i.e. detail and assembly drawings, manufacturing methods and instructions, specifications, recommended suppliers and schedules.

This phase requires the resources of a multi-disciplinary team having specific expertise in each of the vehicle components and sub-systems including the following: power train, vehicle constraints, air-cushion system, variable suspension, vehicle structure, electrical systems, hydraulic & hydrostatic systems, controls, vehicle accessories, cabin and fire-fighting equipment.

Phase II: Prototype Manufacturing:

With manufacturing drawings and technical documents produced in Phase 1, this second phase includes the following activities: general planning of the manufacturing operations, all procurement activities leading to the receipt of equipment and materials, manufacturing methods, sub-assemblies, general assembly, installation and final connections, finishing work, manufacturer trials and preparation for shipment.

Phase III: Site Demonstration and Vehicle Improvements

This phase is the most crucial one of the whole Aerobac development program since it involves operational tests in actual field conditions. Will the Aerobac operate as expected? How well do the two existing and known technologies of the caterpillar traction and air-cushion lift system operate together in an integrated way? Improvements to the design could be required to correct possible problems.

This phase requires proper planning to provide an appropriate level of feedback regarding actual versus desired performance. This would help introducing timely solutions to problems encountered.

The Aerobac prototype would be subjected to about 3 months of operation in winter snow conditions and 3 months of operation in muskeg and other difficult terrain conditions.

This phase has been broken down in two sub-phases:

a) The demonstration itself;
b) Improvements to the design and the refurbishing of the prototype.

8.3 Costs Breakdown Estimates: ($000)

(Aerobac Prototype Procurement)

Phase I - Engineering
Phase II - Manufacturing
Phase III - Demonstration and vehicle improvements

Item/Phase	I	II	III	Total
Material	-	285	50	
Labour	234	173	155	
Expenses	66	10	70	
Total (Vehicle only)	300	468	275	1,043
Fire-fighting equipment	(included)	92	15	107
Grand Total (equipped vehicle)	$300	$560	$290	$1,150

The expenses for the demonstration phase III include $22,500 for the fuel and $25,000 for freight charges from plant to site and return, assuming Montréal-Vancouver scenario.

Phase I: Engineering Cost Estimates ($000)

Labour:		Total
1. Power system	$24.5	
2. Tracks & suspension	28.5	
3. Structure	48.5	
4. Cabin & Control	15.0	
5. Air-cushion system	28.0	
6. Fire-fighting equipment	14.5	
7. System integration & coordination	15.0	
8. Project management & quality control	60.0	
Total labour		$234
Expenses:		
Travel, clerical, communications	$66.0	66
Total phase I		$300

Phase II: Manufacturing Cost Estimate ($000)

Items:	Labour	Material	Expense	Total
1. Power system	22	82		104
2. Tracks & suspension	20	40		60
3. Chassis structure	33	25		58
4. Cabin & control systems	17	20		37
5. Air-cushion system	26	88	5	119
6. Others, assemblies, finishing	15	30		45
7. Expenses: travel, clerical, communi-cations			5	5
8. Project management & quality control	40			40
Sub-total	$173	$285	$10	$468
Fire-fighting Equipment	22	70		92
Total phase II				$560

Phase III: Demonstration and Vehicle Modifications ($000)

Sub phase	III-A Demonstration	III-B Improvements	Total
Labour	$ 60	$100	$160
Material	25	30	55
Expenses	65	10	75
Total	$150	$140	$290

8.4 Production Units

Production units are expected to cost less than the prototype. The developement costs are not repeated, some economy advantage could be gained through larger volume purchasing of equipment and raw material and also the organization of the production run to increase productivity when producing in quantity.

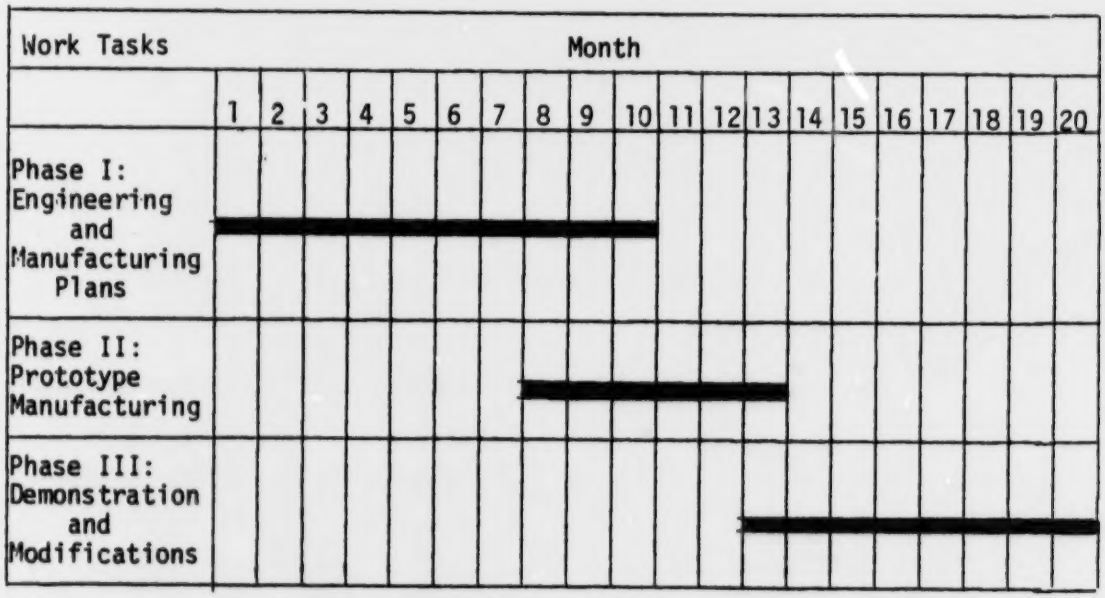
The following is the breakdown of the price components of a fire-fighting equipped Aerobac when produced at a rate of 10 vehicles per year.

	Estimate ($000)
Equipment and material	$264
Labour: (2000 hours at $33/hr)	66
Total mfg. cost	$330
Warranty costs, Administration, financing, licencing, sales and distribution costs and profit, 40% of price (Industry: 30 to 50%)	220
Total	$550

The vehicle price (1983$) is estimated at $550,000 for a production rate of 10 vehicles per year.

8.5 Schedule

An Aerobac prototype is expected to be available for testing about 12 months after the start of the engineering work. The schedule is as indicated below. As it can be seen, the overall program is expected to take 20 months for completion.


Work Tasks
Month
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20
Phase I: Engineering and Manufacturing Plans
Phase II: Prototype Manufacturing
Phase III: Demonstration and Modifications

9. CONCLUSIONS AND RECOMMENDATIONS

9.1 Conclusion

The Aerobac AB-7 in its revised design has been shown to be capable of performing as an airport emergency service vehicle. The simulation of its performance has been compared to an existing airport fire-fighting all terrain wheeled vehicle, the Foremost Delta Three B-4S.

9.1.1 Speed Analysis

In general, the Aerobac and the wheeled vehicle can be compared as follows:

a. Speed-soil strength relationship for slopes of 0-2% on SNOW, MUSKEG and MUDFLAT Terrain.

The Aerobac performs reasonably well on snow and on muskeg of cone index values lower than 100.

The Aerobac has some mobility on mudflat areas such as those found just outside the Vancouver airport, even when the cone index value is as small as 5. It reaches a speed of 48 km/hr on mudflats of 20 to 36 cone index values whereas the wheeled vehicle does only 3.2 km/hr for the same range of cone index values.

This efficiency depends highly on the air-cushion system which is used to relieve the track bearing pressure.

The wheeled vehicle is either totally immobilized or slow moving on those low bearing capacity terrain.

The Aerobac outperforms the referenced vehicle on muskeg with cone index values lower than 125.

b. Speed-soil strength-slope relationship on FINE-GRAINED SOIL.

The Aerobac has a similar performance to the wheeled vehicle in fine-grained soil of high strength (class 1). It has a better performance for low strength soil (class 6) and also for slope climbing, pulling force or acceleration.

c. Speed-soil strength-slope relationship on COARSE-GRAINED SOIL

The Aerobac has a better performance level than the wheeled vehicle on coarse-grained soil of all strength classes and in slope climbing, pulling force or acceleration.

d. Speed-slope relationship on SNOW

The Aerobac outperforms the wheeled vehicle in off-road snow conditions. The wheeled vehicle cannot develop any traction in heavy snow. There are no known vehicles, wheeled or tracked, that can carry 7 tonnes of cargo in deep snow.

9.1.2 Computed Route Travel Times

The vehicle comparative travel times on preselected routes that simulate the road to be followed to reach a hypothetical aircraft crash that could occur at either airport have been computed. The travel times give equal times to both vehicles when the routes cross solid grounds and lower times for the Aerobac in all instances when the routes cross terrain of low bearing capacity, i.e. snow, muskeg, mudflat.

9.1.3 Size and Cost

The Aerobac is a little lower in height; it is twice as wide and is nearly 30% longer than the referenced vehicle.

The Aerobac is estimated to be priced at $550,000 (1983$) while the current Foremost price is $450,000.

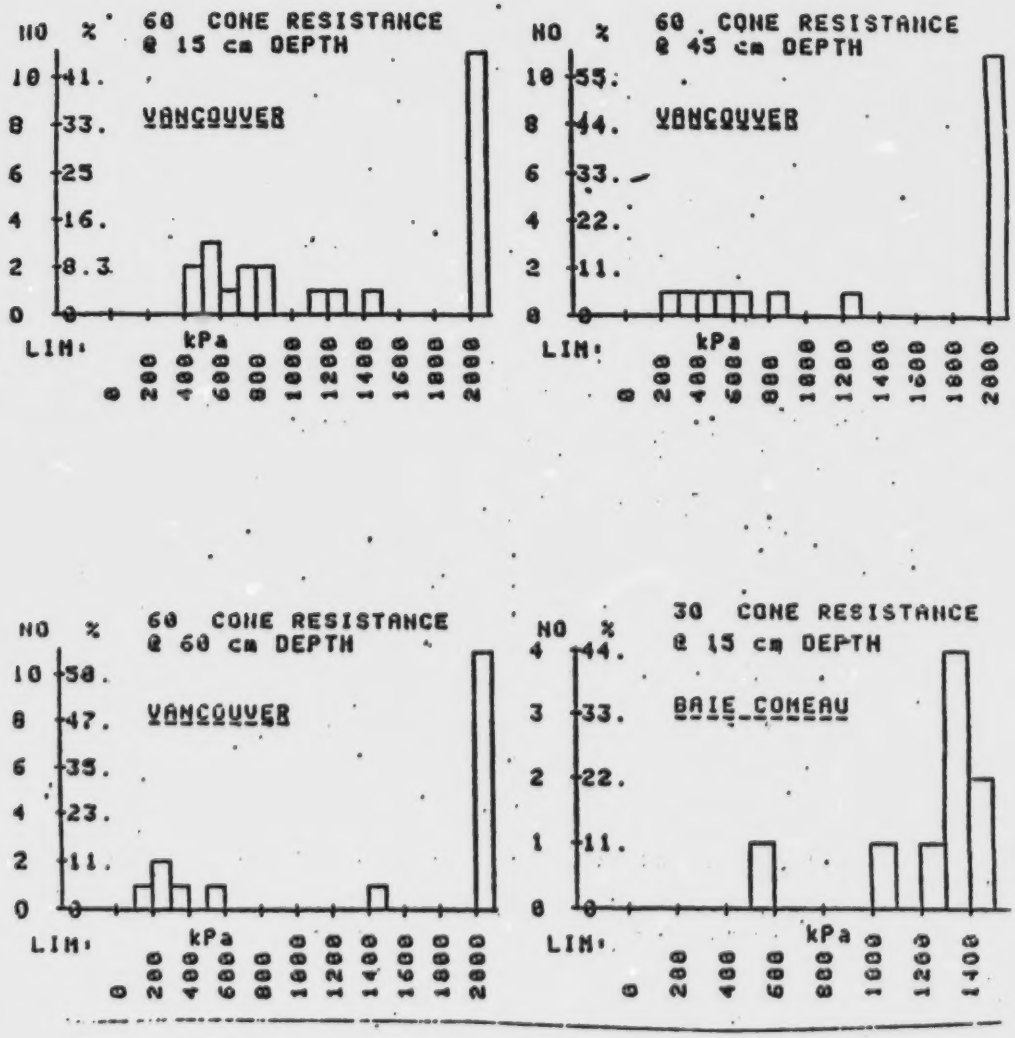
9.2 Recommendations

The Aerobac is recommended for conditions where snow abounds; or in presence of large mudflat or muskeg areas of low soil strength; or when relatively steep slopes, high pulling force or acceleration have to be addressed. The Aerobac may then be the only vehicle capable of performing.

With such positive theoretical results derived in the present study, it is recommended that an Aerobac prototype vehicle be procured to conduct a demonstration in an actual airport environment and that the vehicle be operated by CFR airport personnel. The objective of the demonstration would be to test the actual performance of this new vehicle, verify that it would operate satisfactorily, and if not, perform the modifications to make it meet the design objectives and those of Transport Canada's CFR.

There is no doubt that if the recommended demonstration confirms the expected performance, the Aerobac off-road and amphibious vehicle will find some applications, not only in Canadian airports, but in many countries around the world and answer unsatisfied desired requirement objectives of Transport Canada and of the International Civil Aviation Organization.

FIGURES



(The value of 2000 kPa cone resistance signifies that the soil was too stiff to be penetrated by the cone)

Fig. 1 Cone Penetration Histograms

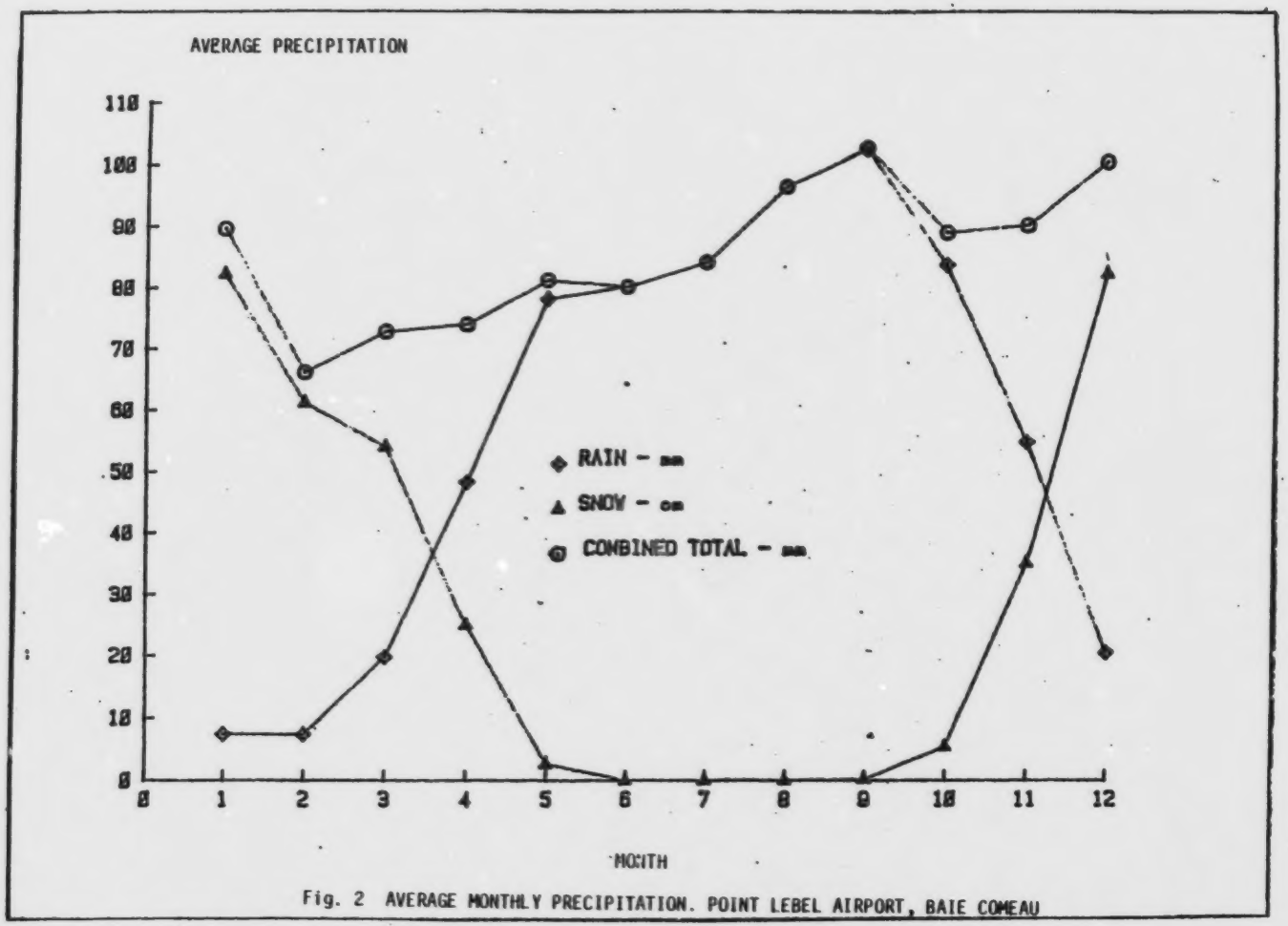


Fig. 2 AVERAGE MONTHLY PRECIPITATION. POINT LEBEL AIRPORT, BAIE COMEAU

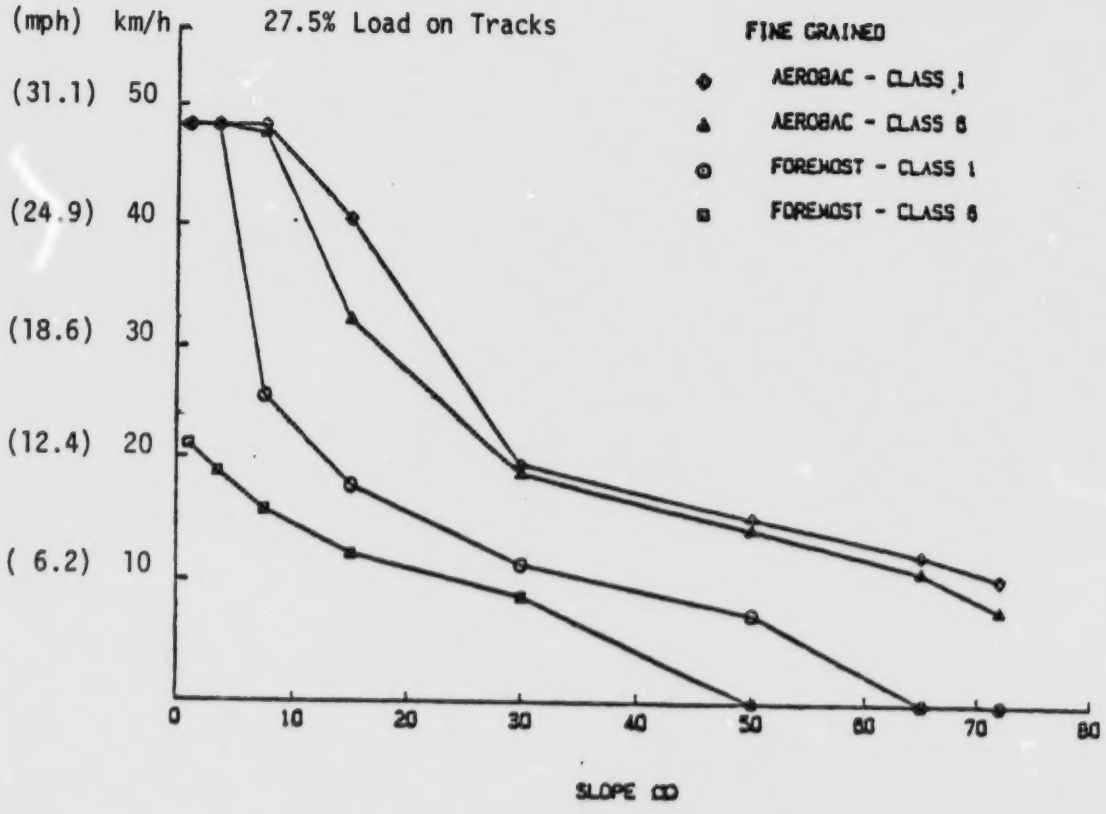


Fig. 3 Speed-Slope Relationships for Fine-Grained Soils

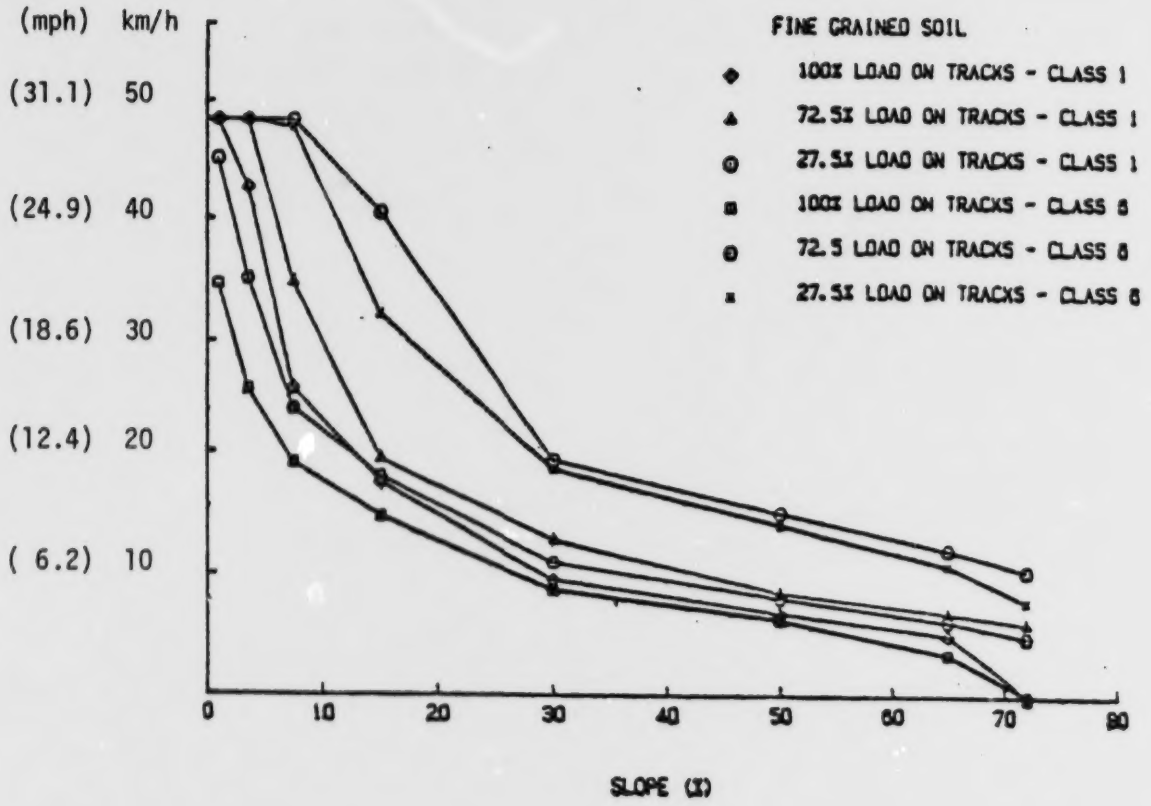


Fig. 4 Effect of Air-Cushion Pressure on Aerobac Performance - Fine-Grained Soils

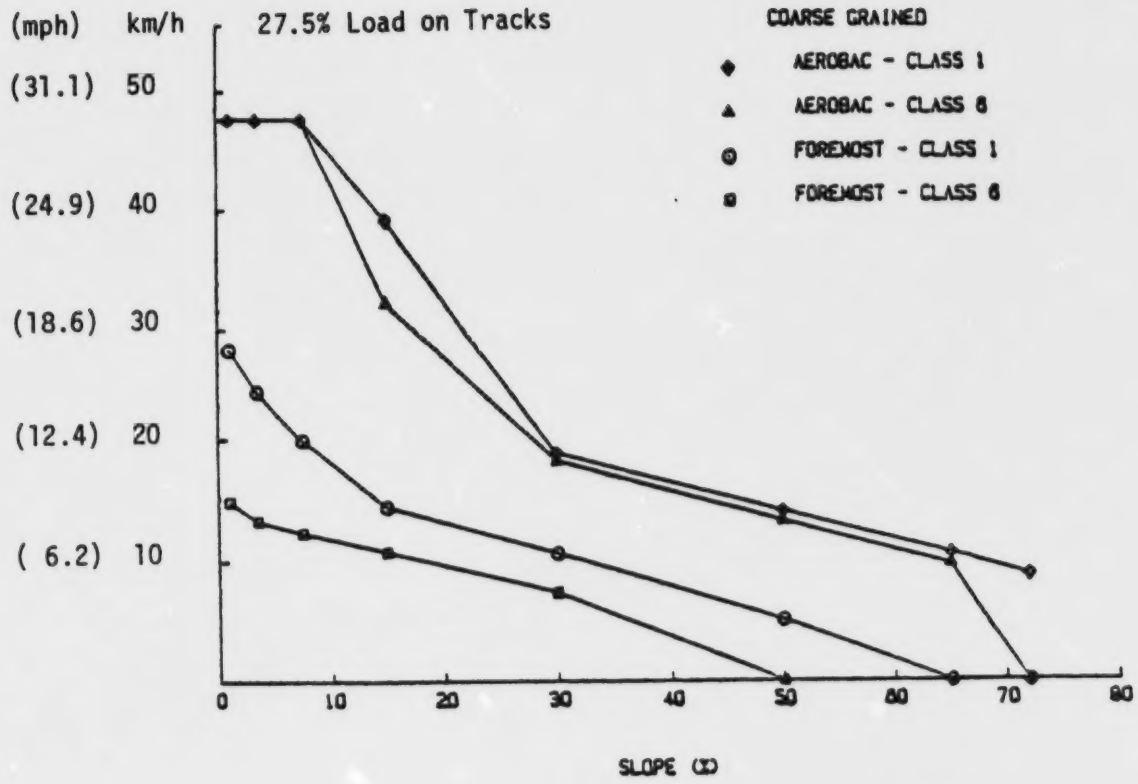


Fig. 5 Speed-Slope Relationships for Coarse-Grained Soils

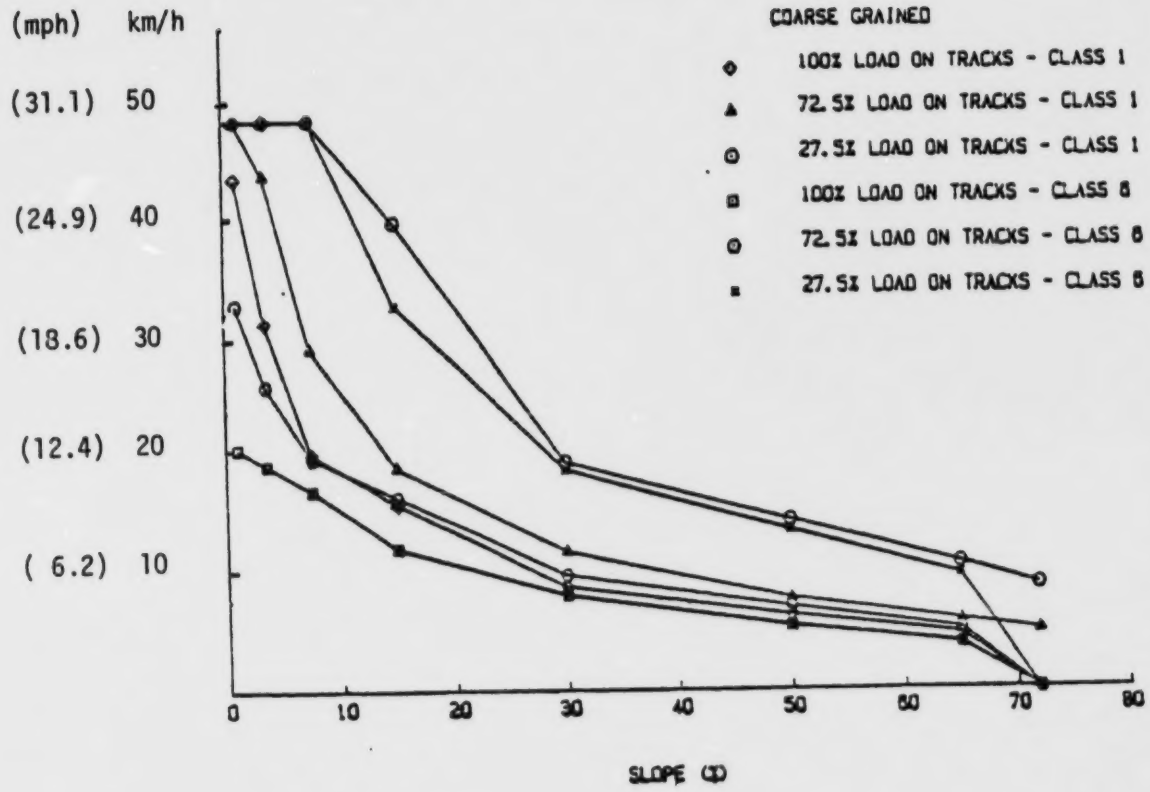


Fig. 6 Effect of Air-Cushion Pressure on Aerobac Performance - Coarse-Grained Soils

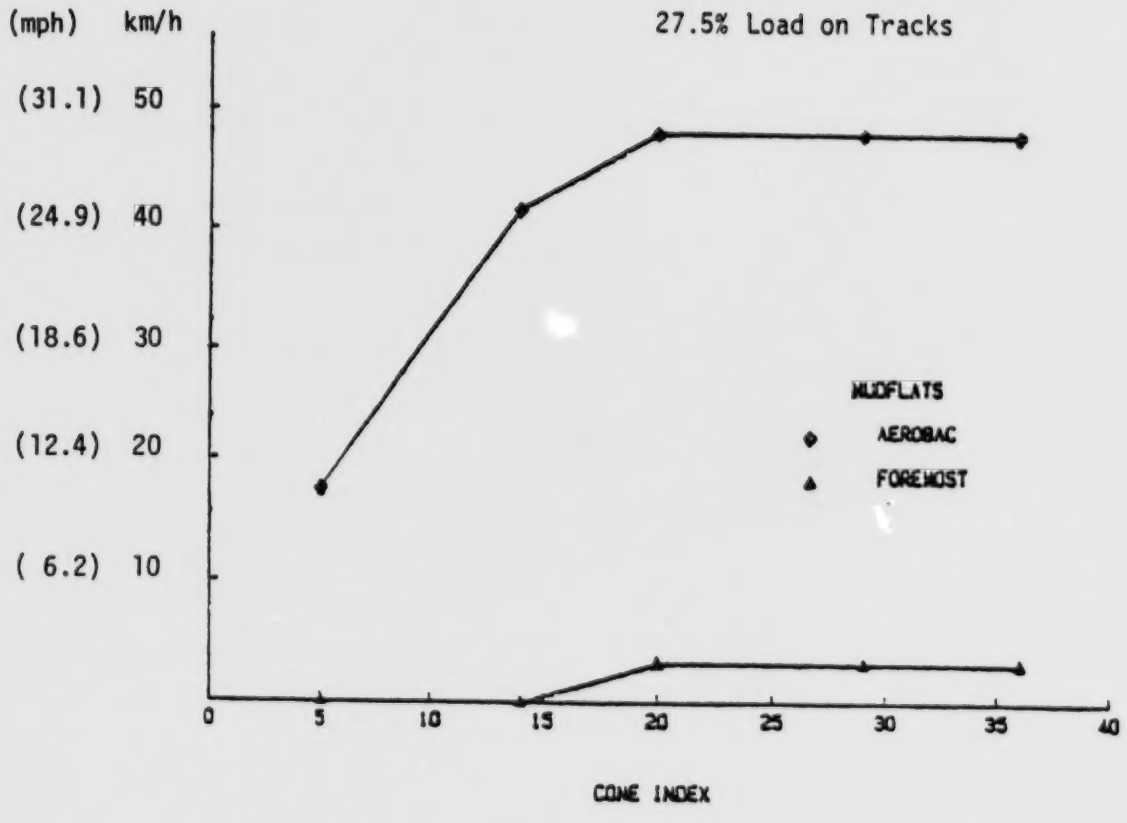


Fig. 7 Speed-Soil Strength Relationships for Mudflats Terrain

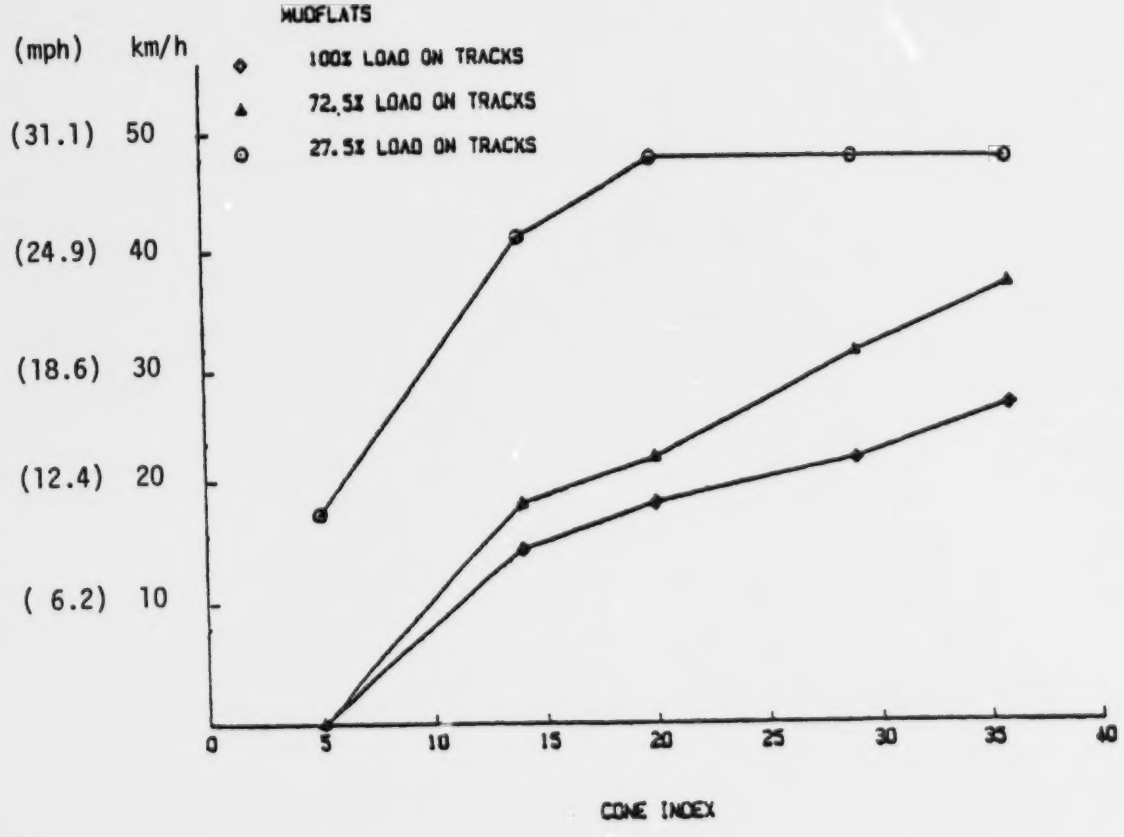


Fig. 8 Effect of Air-Cushion Pressure on Aerobac Performance - Mudflats

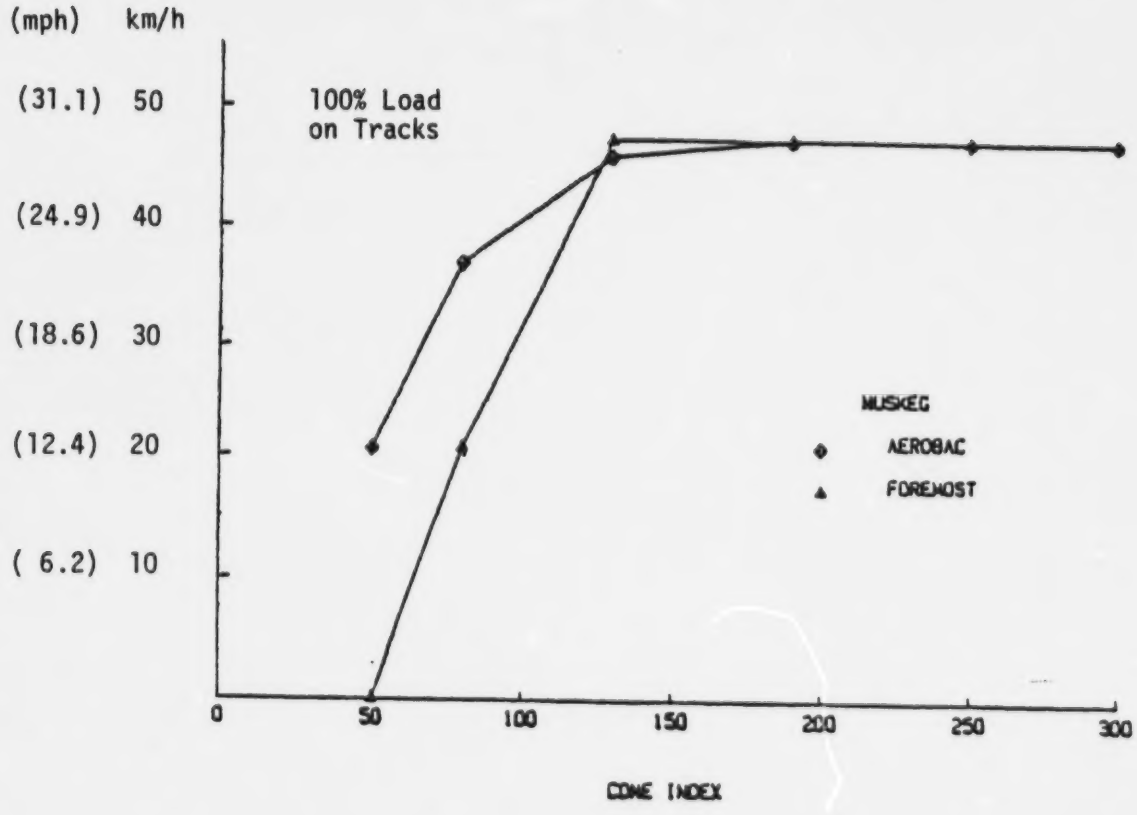


Fig. 9 Speed-Soil Strength Relationships for Muskeg

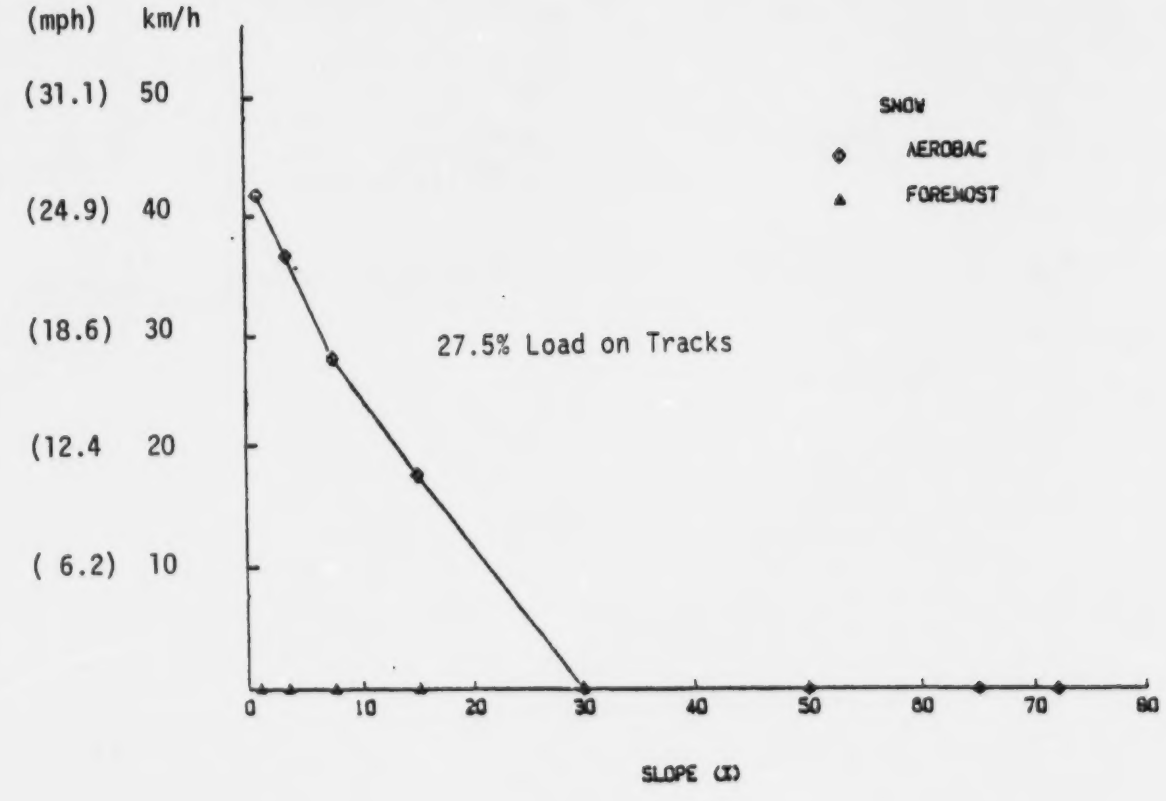


Fig. 10 Speed-Slope Relationships for Snow

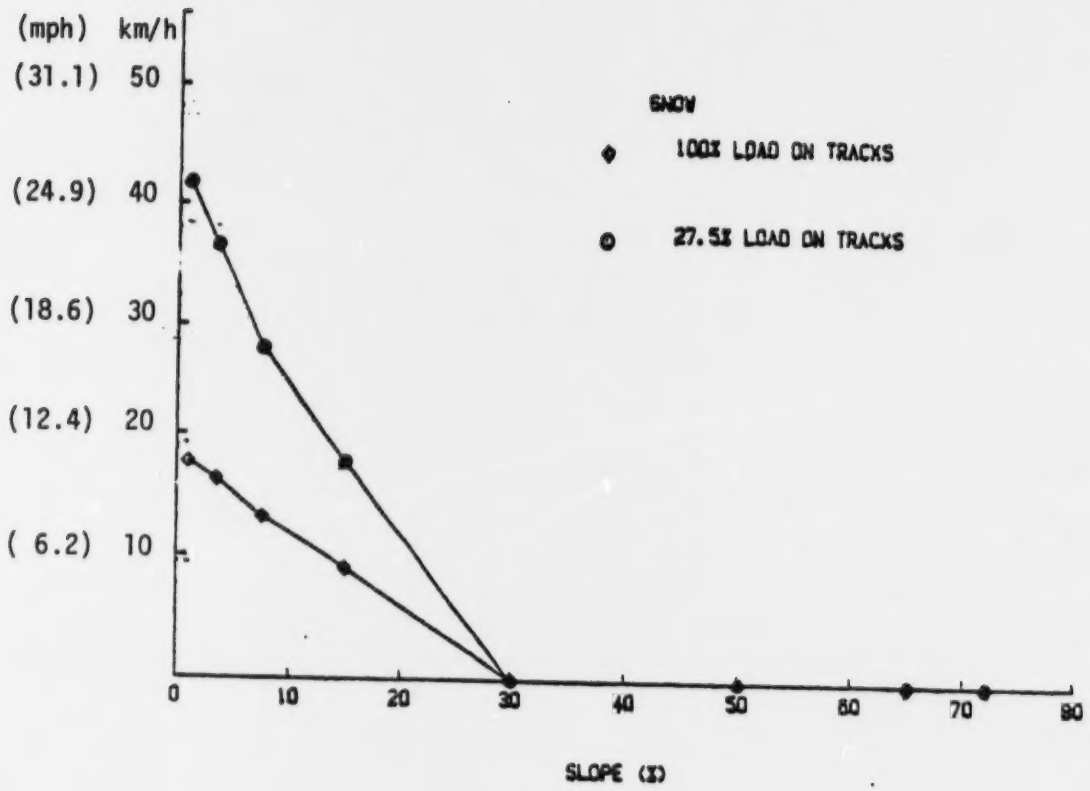


Fig. 11 Effect of Air-Cushion Pressure on Aerobac Performance - Snow

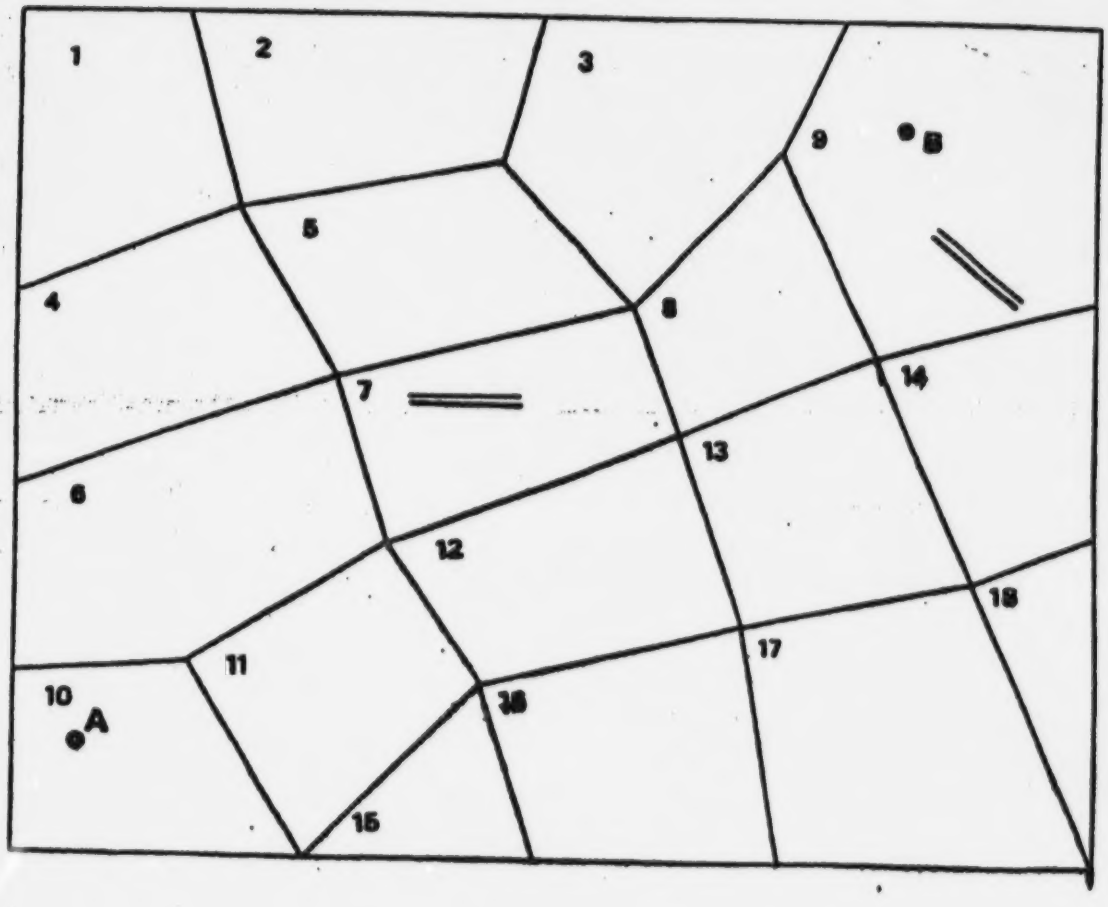


Fig. 12 Schematic Presentation of Map Area Classified into Terrain Units with Points A and B Representing Point of Origin and Point of Destination Respectively

TABLES

Table 4.1

LABORATORY TESTS - SUMMARY SHEET

SITE Vancouver International Airport DATE May 30 to June 3 1983 REF. DRW'G. _____

PROJECT AEROBAC TESTED BY GRC SHEET 1 OF 2

SAMPLE NO		LOCATION		GRAIN SIZE ANALYSIS % PASSING									W_N %	W_L %	W_P %	I_P	ORGANIC	U.S.E.D.	γ_t gm/cc	SAMPLE	REMARKS
FIELD	LAB	HOLE	DEPTH	3"	1 1/2"	3/4"	3/8"	4	40	200	0.02	.005	.001									
B1	1	1	15cm					100	99.9	99.5	94.7	62.7	28.9	49.7	80.4	39.3	41.1		MH	1.92	U	
B1	2	1	"					100	98.4	94.7	92.0	62.9	30.5	42.7	71.1	36.3	34.8		MH	–	D	
B2	1	2	"					100	74.7	8.3	–	–	–	12.8	–	–	–		SP-SM	1.91	U	Sandy
B2	2	2	"					100	97.4	88.3	48.6	16.5	10.5	28.7	–	–	–		SM-SC	–	D	Sandy silt
B3	1	3	"					100	99.7	98.9	77.8	35.3	20.3	30.0	55.3	35.10	20.2		MH	2.01	U	
B3	2	3	"					100	99.5	96.9	74.2	30.7	15.8	30.0	56.6	36.6	20.0		MH	–	D	
B4	1	4	"					100	99.3	95.6	71.6	31.4	14.6	44.7	45.5	29.8	15.7		ML	1.82	U	
B4	2	4	"					–	–	–	–	–	–	40.9	56.0	33.3	22.7		MH	1.81	U	
B5	1	5	"					100	99.8	99.0	76.9	24.9	12.6	38.8	63.3	37.5	25.8		MH	1.85	U	
B6	1	6	"					100	99.9	95.6	64.0	29.2	17.8	27.1	47.7	34.7	13.0		ML	1.76	U	
B7	1	7	"					100	93.6	79.1	69.0	35.7	16.8	33.5	49.3	31.6	17.7		ML	1.66	U	
B7	2	7	"					–	–	–	–	–	–	34.0	60.0	37.9	22.1		MH	–	U	
B8	1	8	"					100	99.6	38.4	–	–	–	15.7	–	–	–		SM	1.69	U	Sandy
B9	1	9	"					100	67.6	3.8	–	–	–	3.4	–	–	–		SP	–	D	Sandy
B10	1	10	"					100	98.6	94.2	91.8	62.9	26.3	42.9	72.4	44.9	27.5		MH	1.76	U	
B11	1	11	"					100	96.3	86.6	77.9	49.3	22.3	36.7	57.5	42.0	15.5		MH	1.72	U	
B12								–	–	–	–	–	–	–	–	–	–		–	–	–	No Sample. Similar to B10
B13	1	13	"					100	96.4	76.5	73.2	43.8	18.5	38.3	61.0	39.9	21.1		MH	1.65	U	
B13	2	13	"					100	84.9	76.4	65.7	39.0	11.6	37.7	65.5	41.4	24.4		MH	–	D	
B14								–	–	–				–	–	–	–		–	–	–	No Sample

U = Undisturbed D = Disturbed

Table 4.1 Cont'd

LABORATORY TESTS - SUMMARY SHEET

SITE Vancouver International Airport DATE May 30 to June 3 1982 REF. DRW'G. _____

PROJECT AEROBAC TESTED BY GRC SHEET 2 OF 2

SAMPLE NO		LOCATION		GRAIN SIZE ANALYSIS % PASSING										W_N	W_L	W_P	I_P	ORGANIC	U.S.E.D	γ_t gm/cc	SAMPLE	REMARKS
FIELD	LAB	HOLE	DEPTH	3"	1 1/2"	3/4"	3/8"	4	40	200	0.02	.005	.001	%	%	%						
B15								—	—	—	—	—	—	—	—	—	—		—	—	—	No Sample
B16	1	16	15 cm					100	99.35	99.6	67.2	26.9	14.7	33.9	51.8	—	—		ML	1.95	U	
B17	1	17	"					100	89.4	53.4	45.0	25.3	11.4	22.9	31.7	22.8	8.9		ML	1.98	U	
B18	1	18	"					100	99.7	90.4	64.4	30.0	15.0	23.9	—	—	—		SM-SC	—	D	Sandy silt
B19	1	19	"					100	96.1	38.4	72.4	44.2	20.8	19.8	40.9	30.8	10.1		ML	1.76	U	
B20								—	—	—	—	—	—	—	—	—	—		—	—	—	No Sample
S1	1	S1	"						100		56.0	29.4	16.8	56.84	—	—	—		—	—	D	Sludge
S2	1	S2	"						100		62.1	26.3	15.8	47.31	—	—	—		—	—	D	Sludge

U = Undisturbed D = Disturbed

BRITISH COLUMBIA/COLOMBIE-BRITANNIQUE

	JAN JAN	FEB FÉV	MAR MAR	APR AVR	MAY MAI	JUN JUIN	JUL JUIL	AUG AOÛT	SEP SEPT	OCT OCT	NOV NOV	DEC DÉC	YEAR ANNÉE	CODE CODE	
VANCOUVER INT'L A															
49° 11'N 123° 10'W 3 m															
Daily Maximum Temperature (°C)	5.2	7.8	9.4	12.8	16.5	19.2	21.9	21.5	18.3	13.6	9.0	6.5	13.5	1	Température Maxima-e Quotidienne
Daily Minimum Temperature (°C)	-0.2	1.4	2.1	4.7	7.9	10.9	12.8	12.6	10.1	6.4	2.8	1.2	6.0	1	Température Minimale Quotidienne
Daily Temperature	2.5	4.6	5.8	8.8	12.2	15.1	17.3	17.1	14.2	10.0	5.9	3.9	9.8	1	Température Quotidienne
Standard Deviation, Daily Temperature	1.9	1.4	1.1	0.9	1.0	1.2	1.1	1.0	1.0	0.8	1.2	1.6	0.6	1	Écart Type de la Température Quotidienne
Extreme Maximum Temperature	14.4	18.0	19.4	24.4	28.9	30.6	31.7	33.3	28.9	22.5	18.4	14.8	33.3		Température Maxima-e Extrême
Years of Record	44	44	44	44	44	44	44	44	44	43	44	44			Années de Relèves
Extreme Minimum Temperature	-17.8	-16.1	-9.4	-3.3	0.8	3.9	6.7	6.1	0.0	-3.3	-12.2	-17.8	-17.8		Température Minima-e Extrême
Years of Record	44	44	44	44	44	44	44	44	44	44	44	44			Années de Relèves
Rainfall	130.7	107.1	95.1	58.3	51.8	45.2	32.0	41.1	67.1	114.0	147.0	165.2	1055.4	1	Chutes de Pluie
Snowfall	25.7	7.5	6.8	0.3	0.0	0.0	0.0	0.0	0.0	T	2.8	17.5	60.4	1	Chutes de Neige
Total Precipitation (mm)	153.8	114.7	101.0	59.6	51.8	45.2	32.0	41.1	67.1	114.0	150.1	182.4	1112.6	1	Précipitations Totales
Standard Deviation, Total Precipitation	57.7	48.8	37.6	28.2	23.9	27.8	24.3	28.2	38.2	65.1	62.8	48.1	156.7	1	Écart Type des Précipitations Totales
Greatest Rainfall in 24 hours	66.3	43.9	49.3	44.5	28.8	40.4	45.2	31.8	49.5	60.7	61.0	89.4	89.4		Chute de Pluie Record en 24 heures
Years of Record	43	43	44	44	44	44	44	44	44	44	44	44			Années de Relèves
Greatest Snowfall in 24 hours	29.7	18.3	25.9	3.6	T	0.0	0.0	0.0	0.0	0.3	22.1	31.2	31.2		Chute de Neige Record en 24 heures
Years of Record	42	42	44	44	44	44	44	44	44	44	44	43			Années de Relèves
Greatest Precipitation in 24 hours	66.3	43.9	49.3	44.5	28.8	40.4	45.2	31.8	49.5	60.7	61.0	89.4	89.4		Précipitation Record en 24 heures
Years of Record	43	43	44	44	44	44	44	44	44	44	44	43			Années de Relèves
Days with Rain	17	15	15	13	10	10	6	8	10	15	18	19	156	1	Jours de Pluie
Days with Snow	6	2	2	*	0	0	0	0	0	*	1	4	15	1	Jours de Neige
Days with Precipitation	20	16	16	13	10	10	6	8	10	15	18	21	163	1	Jours de Précipitation

TABLE 4.2 Meteorological Data for Vancouver Airport

Table 4.3

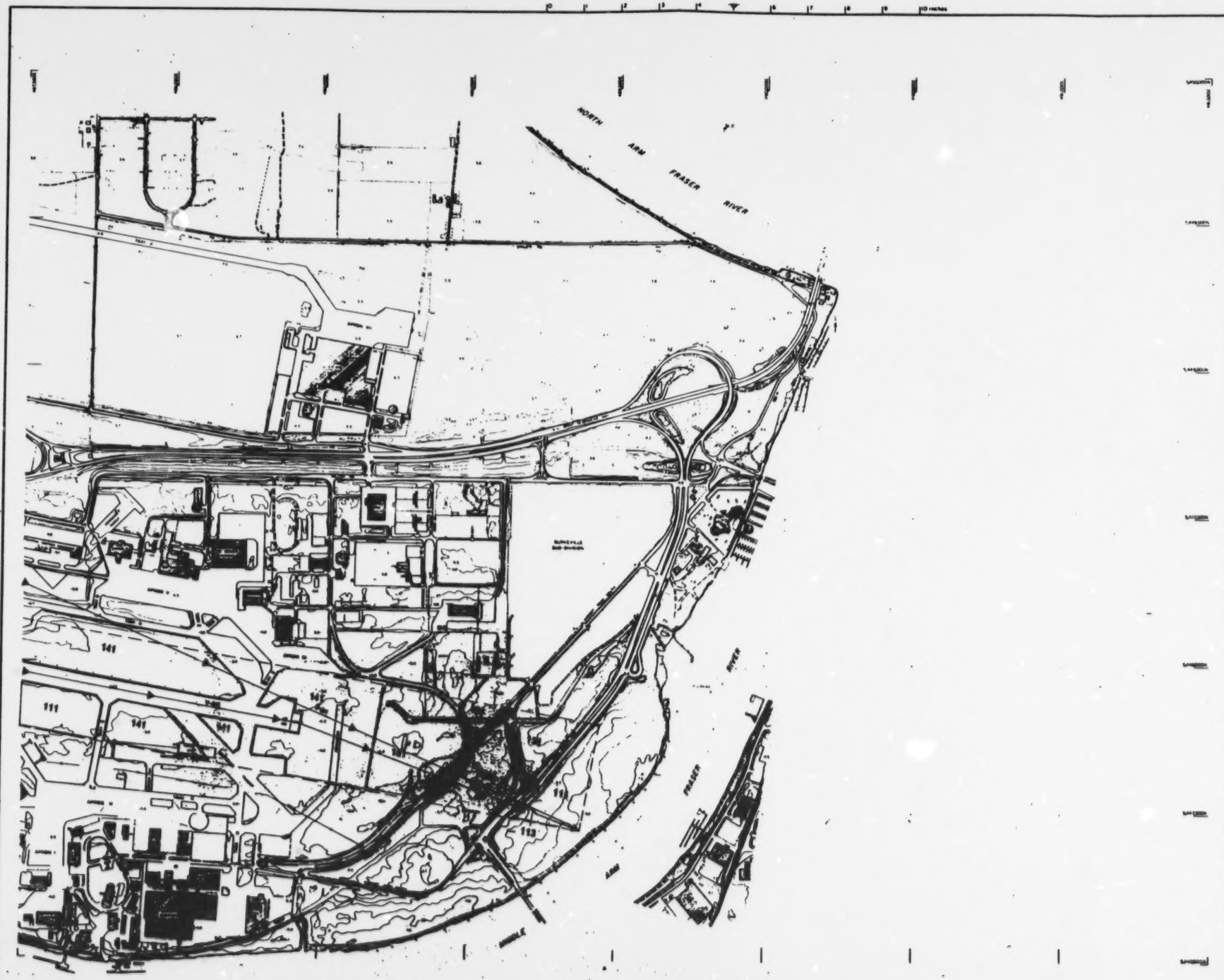
LABORATORY TESTS - SUMMARY SHEET

SITE BAIE COMEAU DATE June 15-17 1983 REF. DRW'G.

PROJECT AEROBAC TESTED BY GRC SHEET 1 OF 1

SAMPLE NO		LOCATION		GRAIN SIZE ANALYSIS % PASSING										W_N %	W_L	W_P	I_P	ORGANIC	U.S.E.D	γ_t gm/cc	SAMPLE	REMARKS
FIELD	LAB	HOLE	DEPTH	3"	1 1/2"	3/4"	3/8"	4	40	200	0.02	.005	.001									
B1	1	1	15cm					100	66.1	6.2				5.0					SP-SM	—	D	
B1	2	1	»					100	47.8	6.4				3.7					SP-SM	1.79	U	
B2	1	2	»					100	55.3	12.5				26.0					SP-SM	1.74	U	
B2	2	2	»					100	58.4	14.6				20.9					SP-SM	—	D	
B3	1	3	»					100	81.2	11.2				18.7					SP-SM	1.57	U	
B3	2	3	»					100	80.6	7.0				16.2					SP-SM	—	D	
B3	3	3	»					100	74.4	7.7				10.8					SP-SM	—	D	
B4	1	4	»					100	83.6	5.9				6.0					SP-SM	1.80	U	
B4	2	4	»					100	48.8	3.7				6.9					SP	—	D	
B5	1	5	»					100	70.4	3.3				3.5					SP	1.85	U	
B5	2	5	»					100	69.7	7.7				3.7					SP-SM	—	D	
B6	1	6	»					100	95.9	9.0				9.9					SP-SM	1.68	U	
B6	2	6	»					100	96.5	6.0				12.7					SP-SM	—	D	
B7	1	7	»					100	79.1	2.5				4.0					SP	1.78	U	
B7	2	7	»					100	79.1	6.1				6.9					SP-SM	—	D	
B8	1	8	»					100	91.6	2.5				5.8					SP	1.74	U	
B8	2	8	»					100	88.6	2.3				5.7					SP	—	D	
B9	1	9	»					100	70.9	9.9				9.3					SP-SM	1.82	U	
B9	2	9	»					100	70.8	8.5				12.5					SP-SM	—	D	
D05	1	10	»					100	60.2	1.6				14.7					SP	1.90	U	Ditch - dyke

DRAWINGS



Transport Canada / Transports Canada
Air / Air

Pacific Region
Construction Services

Région Pacifique
Services de la Construction

SURVEY LIMITS

TERRAIN TYPE LIMITS

VEHICLE ROUTE

MAPPING AND COMPILATION BY BARNETT RESOURCE SURVEYS LTD. FROM AERIAL PHOTOGRAPHY DATED NOVEMBER 1977

GEODETIC CONTROL, STN. STEVESTON: CO-ORDINATES ARE 0° U.T.M.

TRUE NORTH IS 0° 00' 19" EAST OF GRID NORTH

MAGNETIC VARIATION 23° 26' E. (1977) DECREASING 0.1° ANNUALLY

DATUM IS AIRPORT: GEODETIC PLUS 2.680 m = AIRPORT

HORIZONTAL ACCURACY ± 0.5 m

CONTOUR INTERVAL 0.5 m

VERTICAL ACCURACY OF CONTOURS 0.5 CONTOUR INTERVAL

VERTICAL ACCURACY OF SPOT HEIGHTS 0.25 CONTOUR INTERVAL

BUILDING DIMENSIONS ARE ROOF LINE

SERVICE LOCATIONS ARE APPROXIMATE

PIPE SIZES ARE IN IMPERIAL UNITS

VANCOUVER INT. AIRPORT

RECORD PLAN
CONTOURS

1977

METRIC

77-31E-R

Transport Canada / Transports Canada
Air / Air

Pacific Region Construction Services / Région Pacifique Services de la Construction

SURVEY LIMITS

TERRAIN TYPE LIMITS

VEHICLE ROUTE

MAPPING AND COMPILATION BY BARNETT RESOURCE SURVEYS LTD. FROM AERIAL PHOTOGRAPHY DATED NOVEMBER 1977

GEODETIC CONTROL, STA. STEVESTON: CO-ORDINATES ARE 0° U.T.M.

TRUE NORTH IS 0° 00' 19" EAST OF GRID NORTH

MAGNETIC VARIATION 22° 25' E. (1977) DECREASING 0.1° ANNUALLY

DATUM IS AIRPORT: GEODETIC PLUS 2.600 m ± AIRPORT

HORIZONTAL ACCURACY ± 0.5 m

CONTOUR INTERVAL 0.5 m

VERTICAL ACCURACY OF CONTOURS 0.5 CONTOUR INTERVAL

VERTICAL ACCURACY OF SPOT HEIGHTS 0.25 CONTOUR INTERVAL

BUILDING DIMENSIONS ARE NEW LINE

SERVICE LOCATIONS ARE APPROXIMATE

PIPE SIZES ARE IN IMPERIAL UNITS

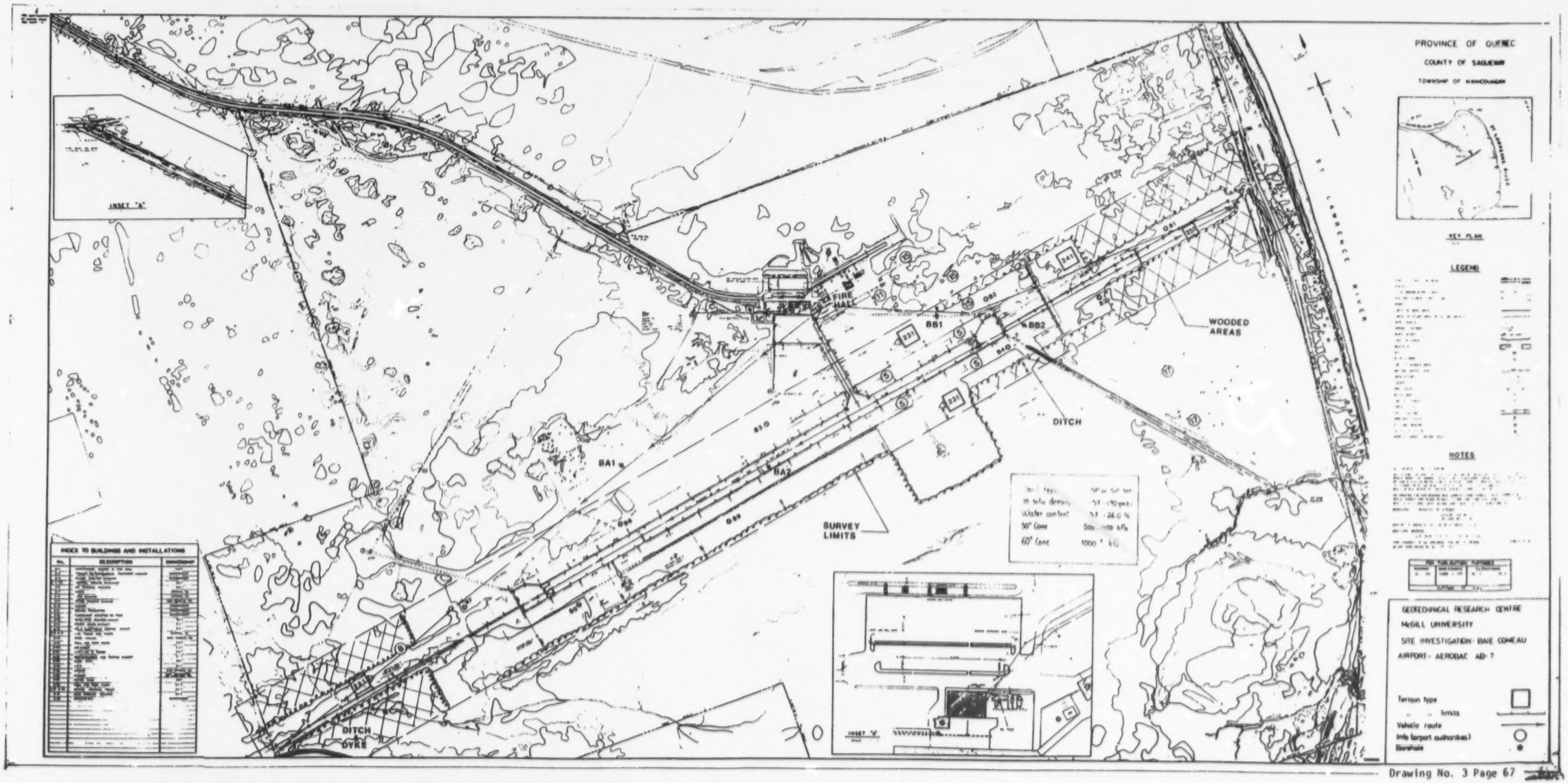
VANCOUVER INT. AIRPORT

RECORD PLAN
CONTOURS

drawn by: D.G.L. | checked by: D.A.V. | approved by: | date: 1977

METRIC

77 - 31 F - R


PROVINCE OF QUEBEC
COUNTY OF SAGUENAY
TOWNSHIP OF BAIE COMEAU
KEY PLAN
LEGEND
NOTES
INSET "A"
FIRE HALL
BB1
BB2
WOODED AREAS
DITCH
BA1
BA2
SURVEY LIMITS
DITCH
DYKE
INDEX TO BUILDINGS AND INSTALLATIONS
GEOTECHNICAL RESEARCH CENTRE
McGILL UNIVERSITY
SITE INVESTIGATION - BAIE COMEAU
AIRPORT - AEROBAC AD-7
Terrain type
Vehicle route
Info (airport authorities)
Borehole

REFERENCES

1. Aérobac AB-7. Etude de faisabilité technique SNC - Transports Canada TP3507F.

2. Implantation de l'Aérobac, SNC - Transports Canada TP2785F.

3. Transport Canada, Airport Emergency Services Part 1 Aircraft Crash Fire Protection Standards, AK-12-03-001, TP3660.

4. Schmertman, (1975) "In situ Measurement of Soil Properties", ASCE, Vol. 2, P. 57.

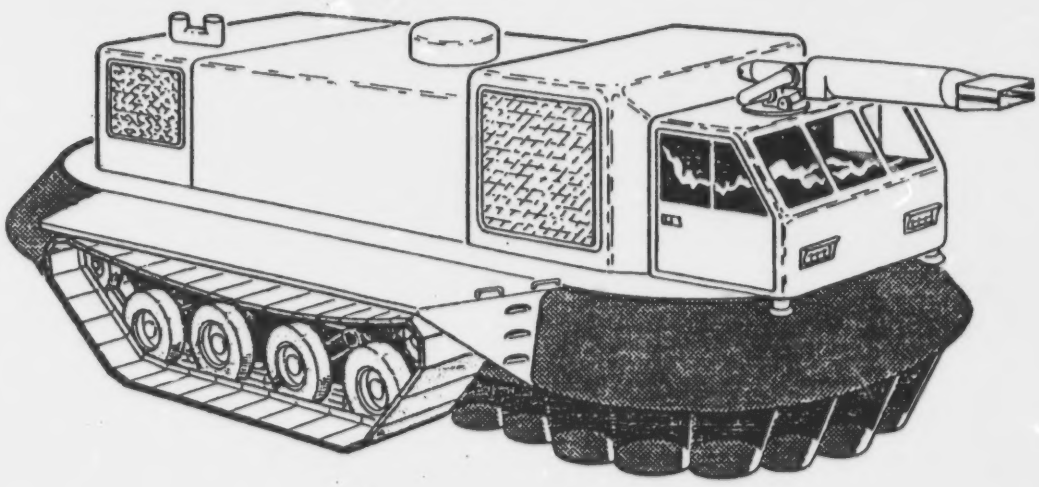
5. Haley, P.W., Jurkat, M.P., and Brady, P.M. (1979) "NATO Reference Mobility Model, Edition 1, Users Guide Vol. I and II", Technical Report 12503, Stevens Institute of Technology, Davidson Laboratory, Hoboken, N.J.

6. Barratt, M.J., "The Wave Drag of an Hovercraft", J. Fluid Mech. (1965) Vol. 22, part 1, pp. 39-47.

APPENDIX A

SPECIFICATIONS OF AEROBAC AB-7 CFR VEHICLE

AEROBAC AB-7 CFR VEHICLE



CHARACTERISTICS

DIMENSIONS
- Overall length.....11.5m
- Overall width.....6.2m
- Overall height.....3.4m
- Chassis structure length.....10.60m
- Chassis structure height.....1.00m
- Skirt height.....0.60m
- Full load weight.....22,525 kg
- Fuel 200ℓ

PERFORMANCES
- Pay load.....7000 kg
- Maximum speed.....60 km/h

- Pressure on ground
  - air-cushion only.....6.7 kPa
  - tracks only.....38.2 kPa
- Maximum performance on slope
  - tracks only.....40%
  - approach angle.....17°
  - amphibious vehicle

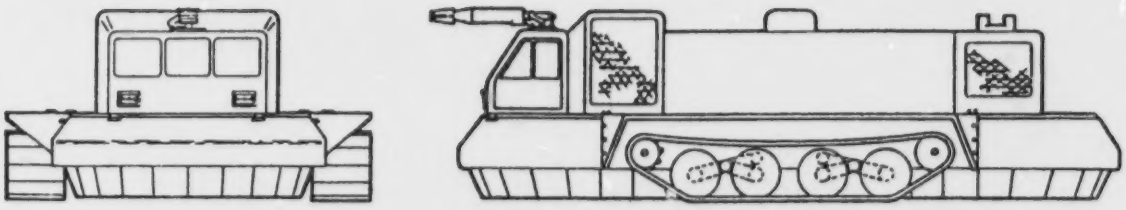
ENGINE
- Manufacturer.....Detroit Diesel
- Model.....12-92TA
- Number of cylinders.....V12
- Kilowatts (brake horsepower)...413 kW (553 (HP) @ 2100 RPM

DRIVE TRAIN
- Transmission type "CLARK "Power Shift"
- Model.....28661

	Gear Ratio	
	High Speed	Lo-Speed
1st	4.84	13.91
2nd	2.29	6.58
3rd	0.84	2.41

- Differential.....LEVY M-24
  - Gear Ratio.....6.1 @ 1
- Sprockets.....0.58 m dia.
  - Location.....Front
- Brakes
  - Service: Multi-discs mounted directly on sprockets driving shafts, foot pedal operation.
  - Parking: A brake on main driving shaft actuated by hand lever.

AEROBAC AB-7 CFR VEHICLE



AIR CUSHION SYSTEM
- Fans.
  - Quantity 2
  - Manufacturer.....VIM
  - Model.....HCHB-040
  - Total flow.....20 m^3/s
- Transmission.....Hydrostatic
- Skirts.....SEDAM multicell system (peripheric adjacent cells) Biconical front skirts and off-road bioconical in the back.
- Air distribution ....left and right cells supplied separately by two ducts with individual opening per cell.

HYDROSTATIC SYSTEM
- Traction
  - type.....SUNDSTRAND series 24
- Fans
  - type.....SUNDSTRAND series 25
- Fire-fighting equipment
  - type.....SUNDSTRAND series 21

ELECTRIC SYSTEM
- Voltage.....12V

SUSPENSION
- Type ..... Independent, adjustable height with torsion bars

WHEELS
- Quantity.....8
- Tires.....Solid rubber
- Dimension.....825 x 15

TRACKS
- Type
  - Rubber belting and steel struts
  - Width.....1.00 m

CHASSIS STRUCTURE
- Type..Welded aluminum structure with waterproof compartments to provide floatation

CABIN
- Type.....3-seater aluminium installed on rubber pads, thermal insulation, heater and defroster, adjustable driver's seat, emergency hatch in roof.

FIRE-FIGHTING EQUIPMENT
- Water.....4500 ℓ
- Fire pump delivery..2500 ℓ/min

December 1983

APPENDIX B

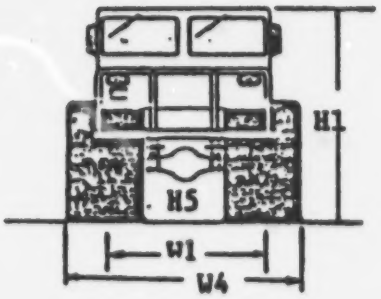
SPECIFICATIONS OF FOREMOST DELTA THREE B4-S

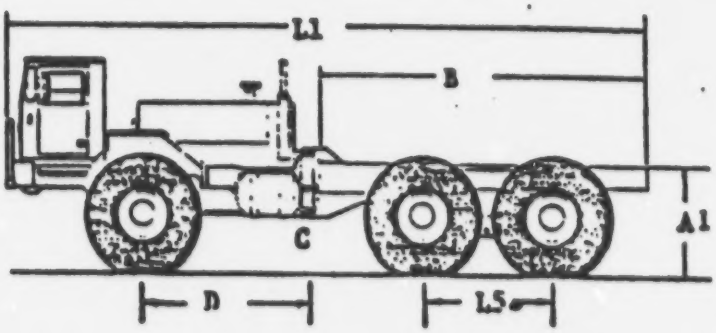
CANADIAN FOREMOST LTD.

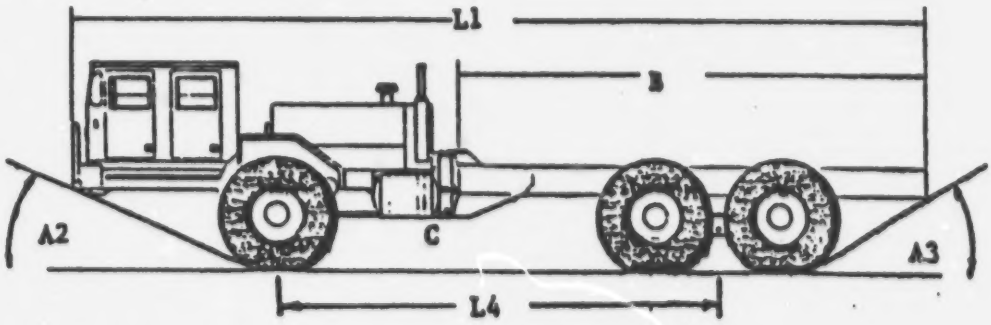
DIMENSIONAL DATA

(SAE J1234)

DELTA THREE B







(See attached pages for dimensions)

CANADIAN FOREMOST LTD.
DIMENSIONAL DATA
DELTA THREE S

DIMENSIONAL DATA (SAE J1234)

	4S*	4L*
Length		
Overall (L1)	30 ft. 1 in. (9.17 m)	35 ft. 5 in. (10.80 m)
Height		
Overall (H1)	9 ft.11 in. (3.02 m)	9 ft. 11 in. (3.02 m)
W/O Tires	8 ft.4.5 in.(2.55 m)	8 ft.4.5 in. (2.55 m)
Rear of Frame (A1)	4 ft. 8 in. (1.42 m)	4 ft. 8 in. (1.42 m)
Width		
Overall (W4)	10 ft.10 in. (3.30 m)	10 ft. 10 in. (3.30 m)
W/O Tires	8 ft. 6 in. (2.59 m)	8 ft. 6 in. (2.59 m)
General		
Frame Width	34 in. (864 mm)	34 in. (864 mm)
Ground Clearance(H5)	21 in. (533mm)	21 in. (533 mm)
Chassis Clearance at Articulation (C)	28.5 in.(724 mm)	28.5 in.(724 mm)
Track (W1)	7 ft.2.75 in.(2.20 m)	7 ft.2.75 in. (2.20 m)
Wheelbase (L4)	16 ft.6.5 in. (5.04 m)	20 ft.4.5 in. (6.21 m)
Tandem Spacing (L5)	6 ft. 0 in. (1.83 m)	6 ft. 0 in. (1.83 m)
Front Axle to Articulation (D)	7 ft.9.5 in. (2.37 m)	7 ft.9.5 in. (2.37 m)
Fording Depth	4 ft. 6 in. (1.37 m)	4 ft. 6 in. (1.37 m)
Turning Radius (SAE J695)	26 ft. (7.92 m)	32 ft. (9.75 m)
Approach Angle (A2)	36°	36°
Departure Angle (A3)	60°	43°
Deck		
Length (B)	15 ft. (4.57 m)	20 ft. (6.10 m)
Width	8 ft. 6 in. (2.59 m)	8 ft. 6 in. (2.59 m)
Live Roll Height	6 ft. 9 in. (2.05 m)	6 ft. 9 in. (2.05 m)
WEIGHT		
Tare	28,000 lbs.(12 700 kg)	28,300 lbs.(12 900 kg)
Payload	30,000 lbs.(13 600 kg)	30,000 lbs.(13 600 kg)
G.V.W.	58,000 lbs.(26 300 kg)	58,300 lbs.(26 500 kg)

* 4S - 4 Man Cab, Short Wheelbase
* 4L - 4 Man Cab, Long Wheelbase

CANADIAN FOREMOST LTD.
PERFORMANCE DATA
DELTA THREE B

PERFORMANCE DATA

Engine: DDA 6V53N45, 197 BHP(147 kW) @ 2800 RPM
Transmission: Clark HR28420
Converter: Clark C-270 Series (2.728:1 stall)
Differential: Clark 191700 (22.349:1)
Tires: Goodyear 66 x 43.00 x 25-4 PR Super Terra Grip

	GROUND SPEED[1]		TRACTIVE EFFORT[2]		GRADEABILITY[2]	
Gear(Fwd/Rev.)	MPH	km/hr.	Lbs.	kN	Forward %[4]	Side %[3]
1	4.3	6.9	35,430	157.6	60	30
2	8.7	14.0	16,760	74.5	25	30
3	14.4	23.2	9,640	42.9	12	30
4	23.7	38.1	5,340	23.8	4	30

1. Empty vehicle, level and smooth ground, convertor drive
2. Converter at stall.
3. Side slope gradeability is highly dependent on terrain and a 30% side gradeability may only be possible at a low speed.
4. Maximum gradeability for starting is 10% less than maximum gradeability listed above.

POWER TO WEIGHT RATIO (G.V.W.)
3.32 HP/1000 lbs. (3.46 kW/tonne)

FUEL ECONOMY - DDA 6V53N45

	Fuel Consumption U.S.Gal/hr.	Litre/h	Hours of Operation/ 120 U.S.Gal.(454 l)
Average Conditions (40% HP Factor)	4.6	17.4	26.1
Severe Conditions (52% HP Factor)	5.9	22.3	20.3

GROUND PRESSURE

Payload Ton	Payload Tonnes	Pressure[1] PSI	Pressure[1] kPa
0	0	8	55
5	4.5	11	76
10	9.1	13	90
15	13.6	16	110

1. Pressures are based on 0-10 MPH (0-16 km/hr.) speed with all tires equally loaded.

CANADIAN FOREMOST LTD.
DETAIL SPECIFICATIONS
DELTA THREE B

01 SUSPENSION

Front
Semi-eliptical multi-leaf springs full floating, stabilized by three torque rods

Rear
Hendrickson RA40 series, walking beam with rubber bushings, 44,000 lbs.(20 000 kg) capacity, 72 in.(1830 mm) beams

TIRES: Goodyear Super Terra Grip 66 x 43.00 x 25- 6 PR Tubeless
WHEELS: Disc Type

02 DIFFERENTIAL

Clark HD-45-40 planetary type
Ratio: 22.349:1
Spiral bevel crown and pinion
Detroit No-spins, all axles
Front axle speedometer drive, electronic

04 FRAME

Main Frames
Heat treated high strength alloy steel channal rails
Bolted construction

Articulation
Provides 42 degree left & right steering through heavy duty self-aligning ball bushings

05 ENGINE

DDA 6V53N45
Horsepower - 197 HP(147 kW) @ 2800 RPM
Torque - 431 lbs.ft.(584 N.m) torque @ 1500 RPM
SAE Ratings @ 85°F(29.4°C)and 500 ft.(152.4 m)
Variable speed governor
Oil Pan - 30 degrees angularity

AIR FILTER: Donaldson FWC Series
Service Indicator
Replaceable paper element (washable)

OIL FILTER: Remote oil filter
ALTERNATOR: Motorola "SA"Series, 84 amp, 12 volt
MUFFLER: Dual vertical wrapped mufflers with tail spout

06 TRANSMISSION

Clark HR28420
Integral mounted to engine
4 Speeds forward, 4 reverse
Full power shift
Bi-directional PTO, turbine driven
Hydraulic pump drive - SAE "C" 2 & 4 bolt
Dynamic brake (internal oil cooled disc brake)

RATIOS:

GEAR(FWD. & REV.)	RATIO
1	5.18
2	2.45
3	1.41
4	0.78

CONVERTOR: Clark C-270 Series
Integral with transmission
Stall torque ratio 2.728:1
Electric lockup optional

October,1982

CANADIAN FORREMOST LTD.

WEIGHT DISTRIBUTION

BELTA THREE S

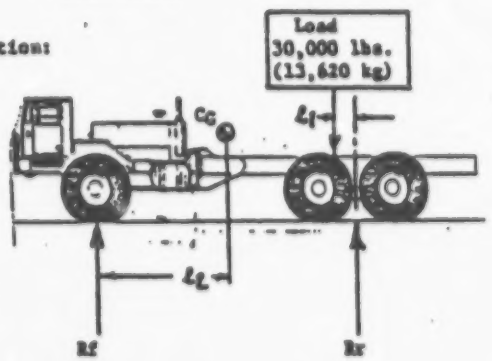
Note: The following weight distribution is based on the following vehicle specification.

Frame: Short Front Frame (for 4 man cab)
Long Rear Frame (for 20 foot (6.1m) deck)

Tires: Goodyear 66x43.00x25-10PR Super Terra Grip

Options: Oilfield Deck - 20 foot (6.1m)
Gin Poles
Deck Winch

Weight Distribution:



	Rf + Rr	Rf	Rr	ℓ_1	ℓ_2
Vehicle Tare	32,100 lbs. (14,570 kg)	14,500 lbs. (6,580 kg)	17,600 lbs. (7,990 kg)		134 in. (3400 mm)
Vehicle Gross	62,100 lbs. (28,190 kg)	20,700 lbs. (9,410 kg)	41,400 lbs. (18,800 kg)	50 in. (1270 mm)	163 in. (4140 mm)

Lino Canada

October, 1982

CANADIAN FOREMOST LTD.

ARTICULATION PIN & BUSHING CAPACITY

DELTA THREE B & TWO B

Bushing Capacity - Foremost # 13-20-143785

	Radial	Thrust
*Recommended Static "Load" Limit	132,000 lbs. (59,900 kg)	53,000 lbs. (24,100 kg)
**Ultimate Static Load Limit	198,000 lbs. (89,900 kg)	79,500 lbs. (36,100 kg)
***Recommended Working Loads	33,000 lbs. (15,000 kg)	13,250 lbs. (6,000 kg)

* Safe operational working loads and should not be exceeded.

** Strict static and impact loading with no motion imparted to the bushing and may be applied conditional to the yield capacity of the housing and shaft mounting.

*** For applications subject to frequent rotation or oscillation under load. For applications with infrequent motion, this limit may be increased correspondingly.

Pin Capacity

Pin capacity allows full usable capacity of the above bushing.

Litho Canada

October, 1982

CANADIAN FOREMOST LTD.

AXLE RATINGS

DELTA THREE S

Front Axle - Clark 17500 Series

Dynamic Capacity	22,500 lbs. (10,200 kg)
Static Capacity	87,500 lbs. (39,700 kg)

Rear Tandem (2 axles) Clark RD45-60 Series

Dynamic Capacity	45,000 lbs. (20,430 kg)
Static Capacity	175,000 lbs. (79,450 kg)

Notes: 1. Above "static capacities" are derived from a typical mobil crane carrier duty cycle.

2. Above ratings vary with tire size and application. For information or assistance on your specific application contact Canadian Foremost Ltd. direct or ask your Sales Representative.

APPENDIX C

LIST OF WORKING DOCUMENTS

LIST OF WORKING DOCUMENTS

1. Dr. P. Boonsinsuk, N. Skiadas

   - Evaluation of the Trafficability of the Aerobac for the Vancouver International and Baie-Comeau Airports. Mc Gill University, Geotechnical Research Centre, July 1983.

2. Dr. Raymond N. Yong

   - Analytical Evaluation of Running Speed for the Aerobac AB-7 for Vancouver and Baie-Comeau Airports, July 1983.

3. M. Letendre

   - Aerobac AB-7, Vehicule d'Urgence Aéroportuaire, Evaluation des Coûts et Prévision d'un Echéancier, Letendre & Associés, Août 1983.

4. - Aerobac AB-7 Véhicule d'Urgence Aéroportuaire, Rapport d'Evaluation (document de travail), D. Gawish, ing., Le Groupe SNC, septembre 1983

5. - Analytical Evaluation of Running Speed for the Aerobac AB-7 for Vancouver and Baie-Comeau Airports according to specifications of new engine and transmission with torque converter and modified differential - final drive reduction ratio. Dr. R.N. Yong, November 1983

6. - Letter to Mr. P.L. Eggleton, photos, map of airport, log of drill holes and a list of tide charts for Vancouver airport, L. D. Howell, April, 1983.

APPENDIX D

EXCERPTS FROM DR. R.N. YONG REPORT

(WORKING DOCUMENT NO. 2)

6.2 Travelling Time

In this section, the travel time for all routes shown on the fold-out maps for Vancouver and Baie Comeau airports are computed for both vehicles. The routes selected represent straight line traverses to point-of-crash - i.e. routes are examined - straight line over whatever terrain, and choice of route over runway. In the case of the Aerobec, the maximum attainable speed (dependent on the air-cushion pressure) for a given power system, is used in calculating the travel time. It should also be noted that in the case of the given route crossing a runway, taxiway or road, it is assumed that the vehicle speed will not change for the terrain unit in which the vehicle is travelling. However, if the vehicle is actually travelling along a paved surface, then the speed is assumed to be the maximum design speed provided no steep slopes are encountered.

Excerpts from:

Dr. R.N. Yong
Analytical Evaluation of Running Speed
for the Aerobac AB-7 for Vancouver and Baie-Comeau
November 1983

6.2.1 Vancouver Airport

(A - Aerobac AB-7, F - Foremost)

a) Route V-A1

Terrain Units Crossed	Distance Travelled (miles)	V_{iA} (mph)	V_{iF} (mph)	t_{iA} (min)	t_{iF} (min)
4	0.8	30	30	1.6	1.6
3	0.074	30	13.5	0.15	0.3
2	0.12	30	12.1	0.24	0.6
Travel Time (min)				2.0	2.5
Mudflats	0.65**	11.2*	0	3.5	-
Travel time (min)				5.5	-

b) Route V-A2

14	0.61	30	30	1.2	1.2
4	0.26	30	30	0.5	0.5
3	0.074	30	13.5	0.15	0.3
2	0.12	30	12.1	0.24	0.6
Travel Time (min)				2.1	2.6
Mudflats	0.65 **	11.2*	0	3.5	-
Travel Time (min)				5.6	

(* based on a cone index value of 5)

** routes V-A1 and V-A2 have been extended into the mudflats to the farthest point of the zone of study. The boundaries are 150 m on each side of the runways, 1000 m at the end of the runways.

c) Route V-B1

Terrain Units Crossed	Distance Travelled (miles)	V_{iA} (mph)	V_{iF} (mph)	t_{iA} (min)	t_{iF} (min)
14	0.86	30	30	1.7	1.7
5	0.16	30	30	0.3	0.3
Travel Time (min)				2.0	2.0

d) Route V-B2

4	0.09	30	30	0.2	0.2
14	0.77	30	30	1.5	1.5
5	0.22	30	30	0.4	0.4
Travel Time (min)				2.1	2.1

e) Route V-C1

Terrain Units Crossed	Distance Travelled (miles)	V_{iA} (mph)	V_{iF} (mph)	t_{iA} (min)	t_{iF} (min)
4	1.30	30	30	2.6	2.6
Travel Time (min)				2.6	2.6

f) Route V-C2

4	0.09	30	30	0.2	0.2
14	0.85	30	30	1.7	1.7
4	0.41	30	30	0.8	0.8
Travel Time (min)				2.7	2.7

g) Route V-D1

4	0.15	30	30	0.3	0.3
4	0.34	30	30	0.7	0.7
4	0.47	30	30	0.9	0.9
8	0.65	30	30	1.3	1.3
10	0.14	30	30	0.3	0.3
11	small	29.6	10.1	0	0
10	0.15	30	30	0.3	0.3
13	small	30	30	0	0
13	0.11	30	30	0.2	0.2
Travel Time (min)				4.0	4.0

h) Route V-D2

Terrain Units Crossed	Distance Travelled (miles)	V_{iA} (mph)	V_{iF} (mph)	t_{iA} (min)	t_{iF} (min)
4	0.09	30	30	0.2	0.2
14	1.53	30	30	3.1	3.1
8	0.17	30	30	0.3	0.3
10	0.12	30	30	0.2	0.2
11	small	29.6	10.1	0	0
10	0.15	30	30	0.3	0.3
12	small	30	30	0	0
13	0.12	30	30	0.2	0.2
Travel Time (min)				4.3	4.3

6.2.2 Baie Comeau Airport

(A - Aerobac, F - Foremost)

a) Route B-A1

Terrain Units Crossed	Distance Travelled (miles)	V_{iA} (mph)	V_{iF} (mph)	t_{iA} (min)	t_{iF} (min)
2	0.03	30	16.3	0.06	0.1
1	0.09	30	30	0.2	0.2
2	1.32	30	16.3	2.6	4.9
Travel Time (min)				2.9	5.2

b) Route B-A2

2	0.03	30	16.3	0.06	0.1
1	0.96	30	30	1.9	1.9
2	0.53	30	16.3	1.1	2.0
Travel Time (min)				3.1	4.0

c) Route B-B1

2	0.49	30	16.3	1.0	1.8
3	0.22	30	14.7	0.4	0.9
4	0.24	30	12.4	0.5	0.8
Travel Time (min)				1.9	3.5

d) Route B-B2

Terrain Units Crossed	Distance Travelled (miles)	V_{iA} (mph)	V_{iF} (mph)	t_{iA} (min)	t_{iF} (min)
2	0.03	30	16.3	0.06	0.1
1	0.58	30	30	1.2	1.2
3	0.22	30	14.7	0.4	0.9
4	0.23	30	12.4	0.5	1.1
Travel Time (min)				2.2	3.3

e) Route B-A1 - Snow-Covered

Distance d_i	V_{iA}	V_{iF}	t_{iA}	t_{iF}
1.44	25.99	0	3.3	-
Travel Time (min)			3.3	-

f) Route B-B1 - Snow-Covered

0.95	25.99	0	2.2	-
Travel Time (min)			2.2	-

y) Muskeg

The following travel times on flat muskeg terrain (slope 0-2%) are based on a straight line distance of 1 km;

Cone Index	V_A (mph)	V_F (mph)	t_A (min)	t_F (min)
300	30	30	1.3	1.3
250	30	30	1.3	1.3
190	30	30	1.3	1.3
130*	29.14	30	1.3	1.3
80*	23.64	13.89	1.6	2.7
50*	13.82	0	2.7	-

* Values representative of the strength of muskeg in Baie Comeau.